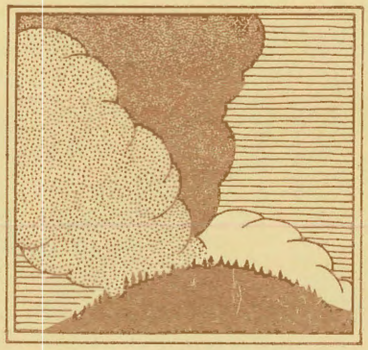
Interim Technical Report
AFSWP – 416
August, 1955

CROWN CHARACTERISTICS OF SEVERAL CONIFEROUS TREE SPECIES

····· Relations between Weight of Crown, Branchwood ·····
and Foliage, and Stem Diameter



DIVISION OF FIRE RESEARCH
FOREST SERVICE
U. S. DEPARTMENT OF AGRICULTURE

ACKNOWLEDGMENT

This study is part of a group research project of the Division of Fire Research, Forest Service, U. S. Department of Agriculture, conducted at the California Forest and Range Experiment Station.

Field work was accomplished by V. M. DeKalb with C. C. Chandler on the Shasta National Forest, California, by George R. Fahnestock at the Priest River Experimental Forest, Idaho, and by Otto J. Brichacek on the Santee Experimental Forest, South Carolina. Statistical computations were performed by Marion S. Hart. Typing of the report was done by Flora M. Doyle.

Agriculture--Berkeley

CROWN CHARACTERISTICS OF SEVERAL CONIFEROUS TREE SPECIES

... Relations between Weight of Crown, Branchwood and Foliage, ... and Stem Diameter

by

Theodore G. Storey, W. L. Fons and F. M. Sauer

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ABSTRACT

Prediction of wind breakage and uprooting in tree stands requires information on weight of dry crown, branchwood, and foliage. This information has not been published. An experimental program started in 1951 has led to a number of generalized relations by which these crown characteristics can be determined with good accuracy over a wide range of tree diameters, species, and species groups.

Crowns, their components--branchwood and foliage--and stems were analyzed for 211 conifer trees representing 13 species and 4 sites from 4 states. Diameters of stems ranged from 1 inch to 37 inches at breast height. Weights of dry crown, dry branchwood, and dry foliage were found to be significantly related to stem diameter at base of live crown for each species provided crown length is taken into account.

Relation for crown weight varied with species and site but not with crown geometry, position of the crown in the canopy, or age. Both branchwood and foliage relations appear to behave similarly.

Crown weight relations for all species were grouped by statistical comparison of regression lines. Resulting groups were rationalized on the basis of similar tree characteristics in an attempt to establish a basis for rating the crown weight of foreign species, or native species not yet analyzed. No firm basis for ratings could be deduced. At a 12-inch stem diameter at base of crown, crowns of shade-tolerant species were not necessarily heavier than those of intolerant trees although they generally had smaller branch-to-foliage ratios. In all species this ratio exceeded 1.0 for trees larger than 5 inches stem diameter at base of crown.

So that results could be applied to stands of trees, the species were grouped to correspond to 11 selected American forest cover types. Equations for weight times length of dry crown for these 11 cover types are presented.

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INTRODUCTION

Determination of relation between certain tree crown[1/] and stem physical characteristics is necessary for the development of a method which predicts tree breakage under the influence of shock-wave winds of the type associated with atomic weapons. Weight of dry crown and its components--dry branchwood and dry foliage--are required to estimate aerodynamic drag forces acting on trees of all sizes and shapes.

This study of tree crown and stem characteristics is one of a number of basic studies (13,16,18,21,23,24)[2/] of physical and mechanical characteristics of trees conducted for the Armed Forces Special Weapons Project leading to a method which predicts tree breakage and uprooting under the influence of strong winds. Wind causes trees to bend, break, and uproot through aerodynamic drag action on foliage, branchwood, and to a lesser extent on main stem surfaces. Drag force has been related to weight of dry crown, a simple indirect measure of crown surface area, for individuals of several coniferous tree species (21). Breakage theory for conifers also requires knowledge of the ratio of weight dry branchwood to weight of dry foliage. Knowledge of the relations between the weight times length of tree crowns and components and their stem diameters and the variations in these relations due to crown geometry, crown class, site class, and age is necessary to allow extrapolation of drag data to trees with crowns of all sizes and shapes that may be found in a forest stand. Determination of species and silvical similarities would allow prediction of crown weight times length for an unfamiliar species, either native or foreign.

Knowledge of the weight times length of tree crowns should find ready application in several other phases of forestry. For example, the foliage weight-stem diameter relation could be used to supplement existing knowledge of litter production from trees and stands for use in soil nutrient and infiltration studies. Quantity of foliage determines the amount of precipitation and solar radiation reaching the forest floor as well as penetration of light through the crowns. The crown canopy intercepts rain and snow and has a retarding influence on the evaporation from the forest floor. Determinations of crown weight would be interest in fire control and forest management to allow prior

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1/ Crown = (Branchwood + Foliage), and does not include the main stem.

2/ Underlined numbers in parentheses refer to Literature Cited, page 91.

estimation of the amount of slash that would be left after logging. Fuel volumes in crowns of standing trees would also be of interest in fire control.

PREVIOUS STUDIES

Much work has been done on quantitative variations of foliage for several coniferous and broadleaf tree species. Very little is known concerning estimation of total crown or branchwood weights. Foliage has been studied intensively by area, volume, weight, and number, all of which are closely related. Quantities have been determined both by sampling and by intensive study of total foliage. However, since few investigators correlated these measures with tree stem characteristics, little of the wealth of published material was directly applicable to the present study. No investigators considered length of crown.

That leaf surface area is related to weight has been well established for both conifers and hardwoods. Tirén (25), working with Scotch pine in Sweden found needle area directly proportional to dry weight at an approximately constant 15-17.5 square meters per kilogram. Chandler (10), studying both forest and fruit trees, found that this ratio is nearly constant for any one species. He concluded that leaf area and dry weight of leaves can be used interchangeably in determining the correlation with some other variable such as interception and transpiration. From intensive work with California black oak and Gambel oak, Sampson (20) found that the ratio of leaf area to dry weight of leaves is fairly constant at from 9 to 11 for both species, although both area and dry weight change as much as 400 percent from spring to fall.

It appears that Tufts (26) was the first to relate weight of tops to tree dimensions. Working with fruit trees he reported high correlation between weight of crown and circumference of the trunk. Correlation coefficient for peach and almond exceeded 0.90. The work of Kittredge (14;15,pp.26-44) wherein he supplements his own work on ponderosa pine and canyon live oak with figures for other species from a variety of published sources, notably Burger (3,4,5,6,7,8,9), is probably the richest source of information. Kittredge tested the relation between leaf weight and diameter of individual trees for 10 species and 28 stands representing a variety of locations, sites, and ages. In all cases trends were linear when data were plotted on double logarithmic paper and thus could be represented by the regression equation:

$$W = -a(D)^b$$

where (W) is leaf dry weight in kilograms and (D) is diameter breast high in inches. The regression coefficients for the data from the United

States and for species native to the United States in Switzerland were tested statistically and all of them proved highly significant. In no cases did the data deviate significantly from linearity. He observed that as a whole the variations in the two constants--from 1.1 to 3.3 for slope and from -0.4 to -2.2 logarithmic units for the intercept--is surprisingly small considering that conifers, deciduous, and broad-leaved evergreen species from California to Vermont and Switzerland, representing a wide range of sites and areas, were included. Furthermore, he concluded that this relation is applicable to trees of different sizes, densities, crown classes, and ages at least up to the age of culmination of growth and beyond that for tolerant species in all-aged stands.

Maruyama (17), working with Japanese red pine (Pinus densiflora, S and Z) in Japan, checked the Kittredge formula for the relation between leaf weight and stem diameter. Maruyama used green weight, which of course changes only the intercept in the regression equation.

Cummings (11), related number of leaves to branch diameter squared for a single silver maple tree but did not give leaf weight data. Rothacher (19) correlated number of leaves with both branch diameter and tree diameter for individual specimens of white, scarlet, and black oak using the relation developed by Kittredge. Average leaf weight data allowed conversion of leaf numbers to weight. He concluded that there is no noticeable influence among sites I to IV on quantity of foliage, and that estimating equations may be applied widely throughout the area typical of the forest type studied.

As breakage theory for conifers shows that drag-force estimation, and thus breakage prediction are quite sensitive to dry crown weight, close estimation of crown weight is essential. Thus, although Kittredge (14) indicates errors of forecast of only about 11 percent are possible when estimating foliage weight directly from diameter breast high for ponderosa pine the present experiment was designed to secure all possible tree measurements in an attempt to develop a more accurate relation for foliage as well as branchwood and total crown weights.

PROCEDURE

This study is based on an analysis of 211 conifers comprising 13 species including pine, cedar, true fir, Douglas-fir, spruce, larch, and hemlock. Four different sites and four states are represented. Individual trees of species comprising several important American cover types were chosen for analysis. Most of the work was done at Mt. Shasta Experimental Forest on the Shasta National Forest in California and at the Priest River Experimental Forest on the Kaniksu National Forest in Idaho. Table 1 lists species and gives site classes and locations from which sample trees were selected.

Table 1.- Site, species, and location of test trees

Species	Tree numbers [a]	Location	Site class [b]	Crown canopy
Ponderosa pine (Pinus ponderosa)	1-12	Mt. Shasta Exper. Forest, Shasta Natl. Forest, Calif. Elev. 4000 ft. (Westside)	II	Semi-open
Ponderosa pine (Pinus ponderosa)	13	Mt. Shasta Exper. Forest, Shasta Natl. Forest, Calif. Elev. 5000 ft. (Eastside)	II	Semi-open
Ponderosa pine (Pinus ponderosa)	14-16	Priest Riv. Exper. Forest, Kaniksu Natl. Forest, Ida. Elev. 3000 ft.	III	Closed
Ponderosa pine (Pinus ponderosa)	17-43	Charleston Ranger Dist., Nev. Natl. Forest, Nev. Elev. 8000 ft.	IV-V	Semi-open
Ponderosa pine (Pinus ponderosa)	44-59	Charleston Ranger Dist., Nev. Natl. Forest, Nev. Elev. 8000 ft.	IV	Semi-open
Sugar pine (Pinus lambertiana)	60-63	Mt. Shasta Exper. Forest, Shasta Natl. Forest, Calif. Elev. 4000 ft. (Westside)	II	Semi-open
Western white pine (Pinus monticola)	64-93	Priest Riv. Exper. Forest, Kaniksu Natl. Forest, Ida. Elev. 3000 ft.	II	Closed
Lodgepole pine (Pinus contorta)	94-97	Mt. Shasta Exper. Forest, Shasta Natl. Forest, Calif. Elev. 4000 ft. (Westside)	II	Semi-open
Lodgepole pine (Pinus contorta)	98-104	Priest Riv. Exper. Forest, Kaniksu Natl. Forest, Ida. Elev. 2500 ft.	III	Closed
Loblolly pine (Pinus taeda)	105-113	Santee Exper. Forest, Francis Marion Natl. Forest, S. Carolina. Elev. 300 ft.	II	Closed
White fir (Abies concolor)	114-122	Mt. Shasta Exper. Forest, Shasta Natl. Forest, Calif. Elev. 4000 ft. (Westside)	II	Closed

See footnotes at end of table, p. 13.

Table 1 (continued)

Species	Tree numbers[a]	Location	Site class[b]	Crown canopy
Grand fir (Abies grandis)	123-125	Priest Riv. Exper. Forest, Kaniksu Natl. Forest, Ida. Elev. 3500 ft.	III	Closed
Douglas-fir (Pseudotsuga taxifolia)	126-131	Mt. Shasta Exper. Forest, Shasta Natl. Forest, Calif. Elev. 4000 ft. (Westside)	II	Closed
Douglas-fir (Pseudotsuga taxifolia)	132-151	Priest Riv. Exper. Forest, Kaniksu Natl. Forest, Ida. Elev. 3000 ft.	III	Closed
Engelmann spruce (Picea engelmannii)	152-165	Priest Riv. Exper. Forest, Kaniksu Natl. Forest, Ida. Elev. 4000 ft.	III	Closed
Western hemlock (Tsuga heterophylla)	166-179	Priest Riv. Exper. Forest, Kaniksu Natl. Forest, Ida. Elev. 3500 ft.	III	Closed
Incense cedar (Libocedrus decurrens)	180-185	Mt. Shasta Exper. Forest, Shasta Natl. Forest, Calif. Elev. 4000 ft. (Westside)	II	Open
Western redcedar (Thuja plicata)	186-200	Priest Riv. Exper. Forest, Kaniksu Natl. Forest, Ida. Elev. 3000 ft.	III	Closed
Western larch (Larix occidentalis)	201-211	Priest Riv. Exper. Forest, Kaniksu Natl. Forest, Ida. Elev. 3000 ft.	III	Closed

[a]Physical characteristics of trees are given in table A-1, Appendix A.

[b]Site--capacity to produce forests as reflected by average height of dominant trees; Site I highest capacity.

Criteria for individual tree selection were dominance, fullness of crown, uniformity of crown, and lack of defect visible from the ground (i.e., fire scar, rot, crook, and fork). Diameters at breast high from 1 inch to 37 inches were sought; however, suitable trees in each diameter class were sometimes not available. Trees were selected from typical associations for the given species. Nearly all trees fit the crown

class I of Dunning (12) for young trees. Tree and crown measurements commonly used in forestry were used to increase utility of the results. All tests were conducted under dry soil conditions except for loblolly pines which were measured on wet soil. All crown analyses were made in mid- or late summer prior to leaf fall.

All species, diameter breast high, site class, and location for each sample tree were recorded. The area around each sample tree then was cleared of all litter and dead branchwood. Height of each sample tree was determined by repeated Abney level observations and checked by actual measurement of the stem after falling. Total height is from the beginning of the current year's growth at the top to one foot above ground at the base. Using the total height each 20 percent section was calculated and marked off on the standing stem, 0-20 percent being at the top of the tree. The tree was then pruned to the 80 percent mark, or the closest 20 percent thereto if live branchwood started above the 80 percent mark. For details of crown division see figures 1 and 2.

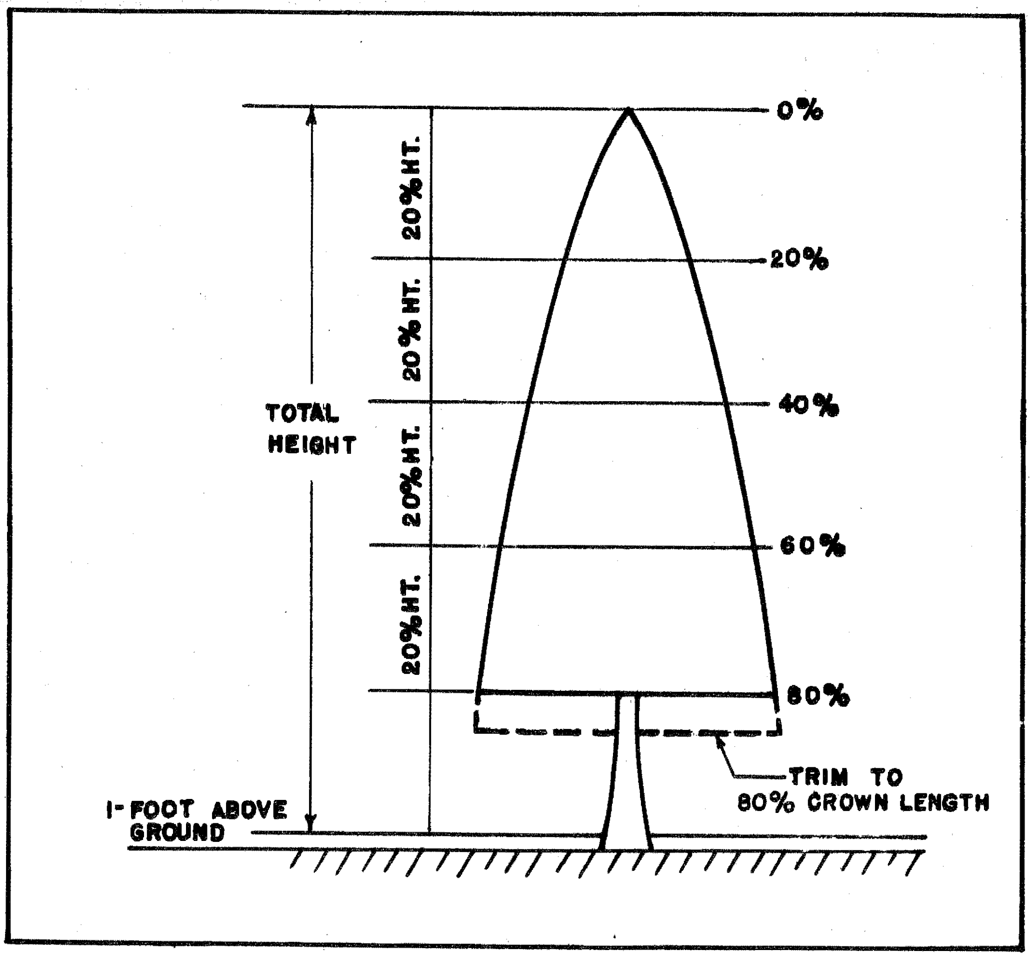

Figure 1.- Tree division for crown analysis

(a) (b)

Figure 2.--Ponderosa pine 124 feet high and 37 inches in diameter at breast height. (a) 60 percent crown, (b) 40 percent crown. (Tree No. 6, Appendix A, table A-1.) Branch stubs, used for climbing, were removed and weighed as branchwood after falling.

The lower 20 percent (60-80 percent) then was pruned of branchwood flush with the stem, and trimmed crown weighed. Stem weight was not considered in this analysis. Moisture samples of needles and branchwood separately were taken immediately, from clumps taken at random from top to bottom of section. About one third of the crown section was laid aside to be stripped for foliage and branchwood analysis. Stripping of foliage was carried on by a second crew while pruning continued. Fascicle sheaths were considered as foliage. Branchwood and foliage were weighed separately following stripping, and another moisture content sample was taken of each. Samples were placed in cans, and moisture content determined later by oven drying at 180°F or by xylene distillation (2).

The next 20 percent crown was pruned, weighed, and sampled for moisture content as before. Again one third of the crown section was saved for stripping, weighing, and sampling moisture. The process was continued until the tree was completely stripped of crown leaving only the bare stem. Finally the stem was cut down, cut at the base of each 20 percent crown section, and average diameter inside bark and stem length measured.

RESULTS AND DISCUSSION

Physical characteristics of crown and stem for each sample tree and calculated dry weights for total crown and its components--dry branchwood and dry foliage--are presented in Appendix A, table A-1. Crown measurements are listed cumulatively by 20 percent crown sections and by other crown sections, as indicated in the table.

Combination of Variables

When the two variables, dry crown weight in pounds (W_{dc}) and stem diameter at breast height in inches (d_{bh}), are plotted on double logarithmic paper (figure 3), as suggested by Kittredge (14) for dry weight of foliage, the trends are linear so that they can be represented by the regression equation:

$$W_{dc} = a(d_{bh})^b \qquad (1)$$

This relation was tested for data from seven ponderosa pines of site class II located near Mt. Shasta, California. The regression coefficient was tested statistically and proved to be highly significant. An additional statistical test showed that the trend did not deviate significantly from linearity. Coefficient of correlation was 0.991 and standard error of estimate was 27 percent of 318 pounds, the mean value of dry crown weight.

To determine whether other combinations of variables would permit closer estimation of weight of dry crown, two further analyses were made of data for the same seven ponderosa pines.

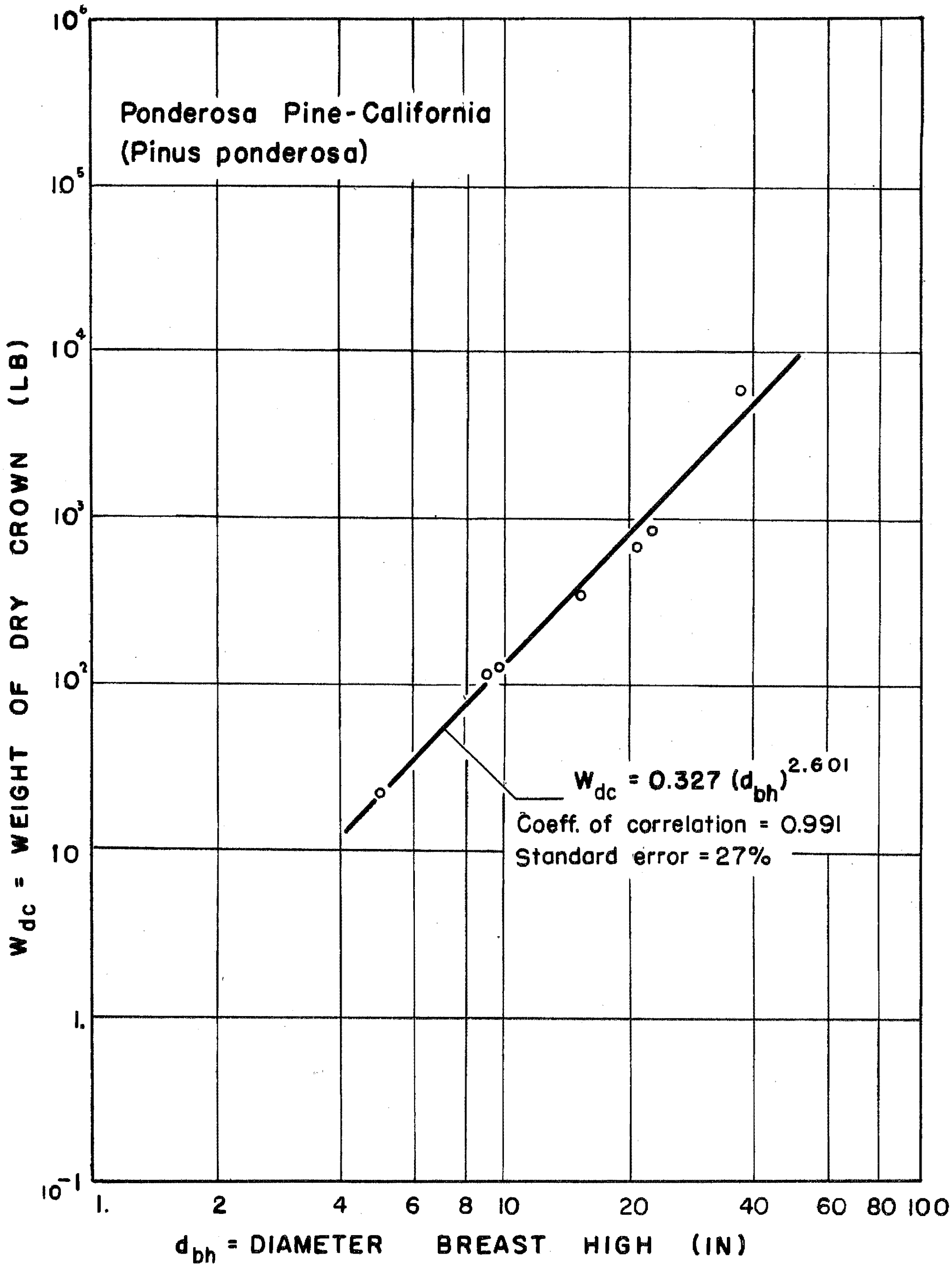

Figure 3.--Relation between dry crown weight and breast high stem diameter outside bark--ponderosa pine (California)

Substitution of stem diameter at base of live crown in inches (d_c) as the independent variable in place of diameter breast high results in an equation of the form:

$$W_{dc} = a(d_c)^b \qquad (2)$$

This form equation (figure 4) decreases standard error of estimate a substantial amount to 16 percent and increases coefficient of correlation to 0.997. Again the regression coefficient was highly significant and there was no departure from linearity. Improvement in estimation of crown weight was obtained even though all trees were of 80 percent crown with base of live crown quite close to breast high. With a wider range in crown length, which is more customary in forest-grown trees, the advantage of using base of crown stem diameter would be even more apparent as this variable corrects for variations in stem form.

When the weight of dry crown is multiplied by the length of live crown in feet (H_c) and stem diameter at base of live crown is retained as the independent variable the following equation results:

$$W_{dc} \cdot H_c = a(d_c)^b \qquad (3)$$

This form equation (figure 5) provides even closer estimation of dry crown weight with an error of estimate of only 7 percent of the mean. Coefficient of correlation becomes 0.999. The regression coefficient is highly significant and no departure from linearity can be demonstrated. Inclusion of the crown length variable improves estimation of crown weight as it provides correction for poor site, old trees, and for natural variations for any given site and age. Older trees, or trees on poor site have shorter, broad crowns on the average, and crown weights tend to be overestimated from the correlation of crown weight alone with diameter at base of live crown (equation (2)). It was also found that slight loss in accuracy results from rearranging the variables in equation (3) into a new equation combining length of live crown with the independent variable (diameter at base of live crown) rather than with the dependent variable.

An analysis similar to that outlined above for weight of dry crown of ponderosa pine was applied to data for the two crown components--dry branchwood and dry foliage. Similar results were obtained. The discussion which follows deals with the more accurate relation similar to equation (3) for both total crown and components.

For this analysis all weights are oven dry. The dryness of the crown, whether oven dry, air dry, or green, changes only the value of the constant (a) in the equation and does not alter the usefulness of the relation for purposes of estimation.

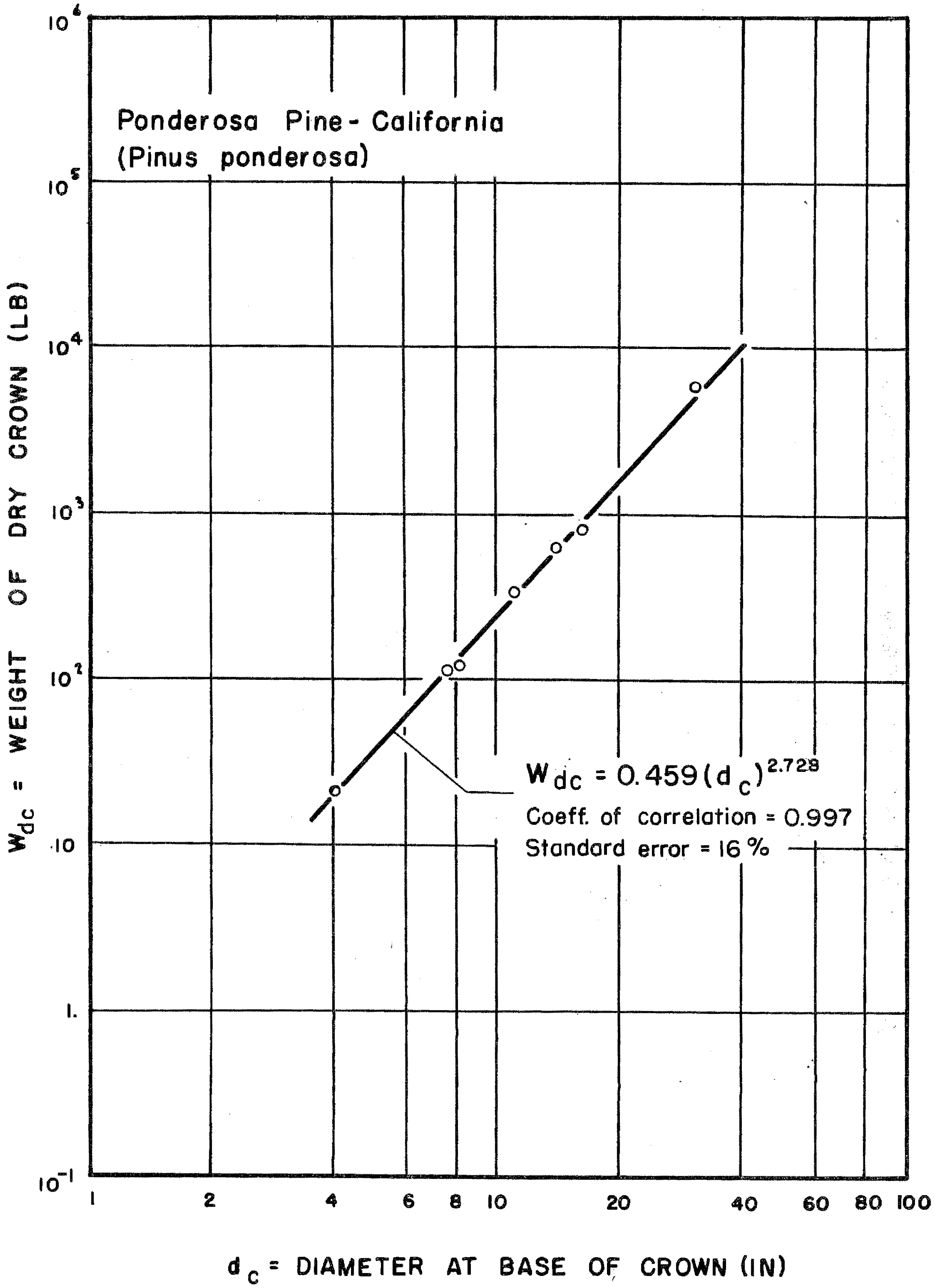

Figure 4.--Relation between dry crown weight and base of crown stem diameter inside bark--ponderosa pine (California)

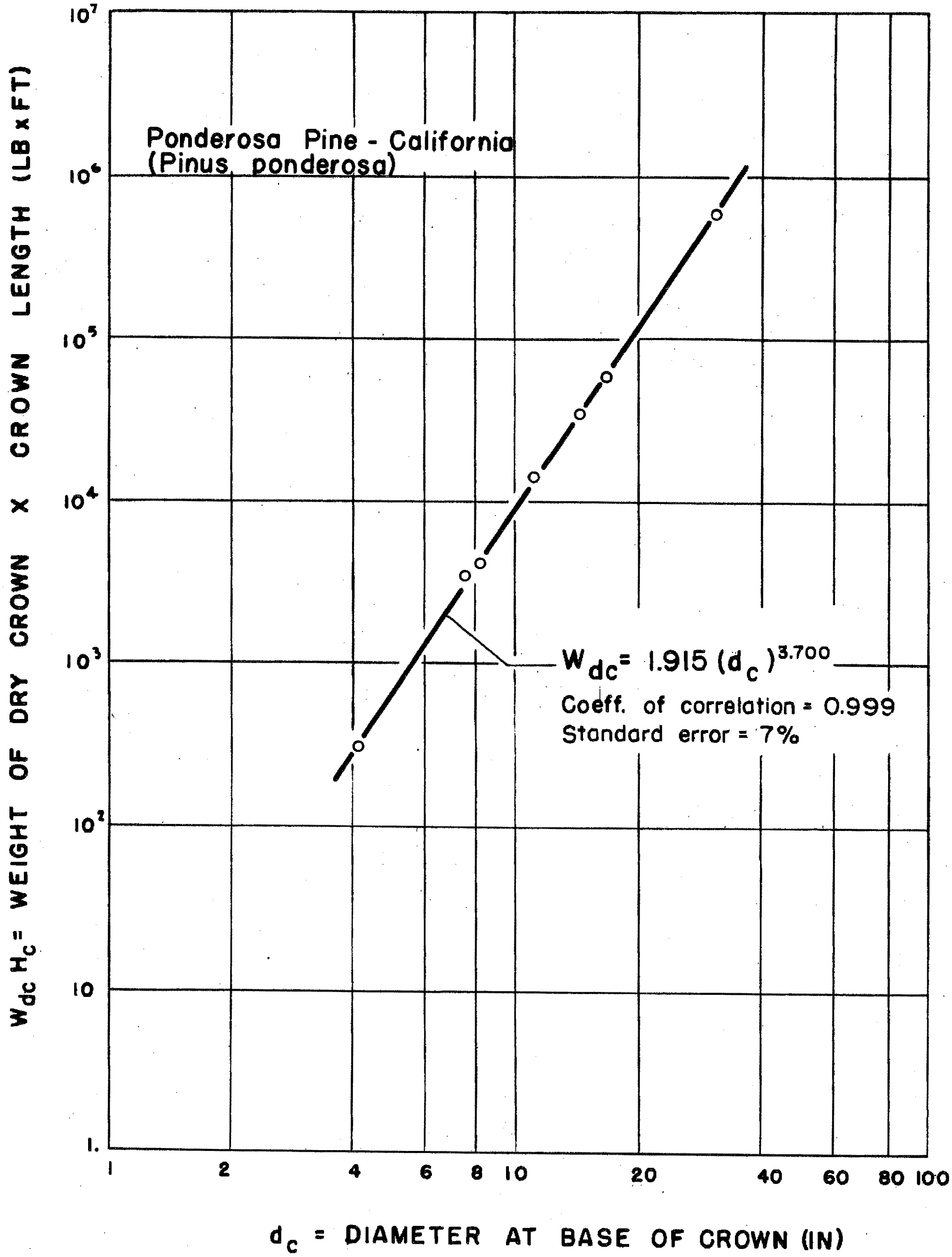

Figure 5.--Relations between dry crown weight, length, and base of crown stem diameter inside bark--ponderosa pine (California)

Crown Geometry

The preceding discussion dealt with only one weight, length, and stem diameter measurement per tree. In addition, crown lengths were all the same percent of total tree height, and smaller diameters were not well represented. To allow extrapolation of correlation between drag force and dry crown weight to all tree sizes and shapes it is necessary to demonstrate geometrical similitude of tree crowns. That is, the same relation between crown weight and length and stem diameter must be shown to hold for both the top of a large tree and a full-crowned small tree. This is necessary before dynamical similitude can be assumed.

For this purpose, data for all crown sections for each ponderosa pine from the Mt. Shasta area of California were plotted in the usual form on a single graph (figure 6). Regression equations were calculated and plotted for 20, 40, 60, and 80 percent crown sections. Constants and statistical measures are given in table 2. Visual comparison of the four curves showed marked parallelism. A statistical test for the significance of differences between both regression coefficients and intercepts by percents crown demonstrated that no significant differences exist, thus effectively showing geometrical similitude of tree crowns of all lengths and sizes for ponderosa pine.

As the four fitted regressions by percent crown for all other species and locations superimposed quite well, similitude was assumed although lack of data precluded the use of statistical analysis. Conclusive proof of this assumption of similitude for species other than ponderosa pine must await further investigation.

Use of all crown sections also increased the number of usable sets of measurements to a maximum of four for each sample tree. This strengthened further analysis by tripling or quadrupling the number of degrees of freedom available for estimation purposes.

This relation for both total crown and components was tested for the 12 additional species which are from a variety of locations, sites, and of several ages. The regression coefficients for all species were tested statistically, and all of them proved highly significant. In the cases in which the greatest tendency toward a curvilinear trend appeared, statistical test showed that the line did not deviate significantly from linearity.

The values of slopes, intercepts, and statistical measures for the equations of the several different species and stands for total crown, branchwood, and foliage are summarized in tables 3, 4, and 5 respectively. Number of data and ranges in data about the trend lines are given in each case. Corresponding graphs are presented in Appendix B, figures B-1 to B-17, figures B-18 to B-26, and figures B-27 through B-35 respectively.

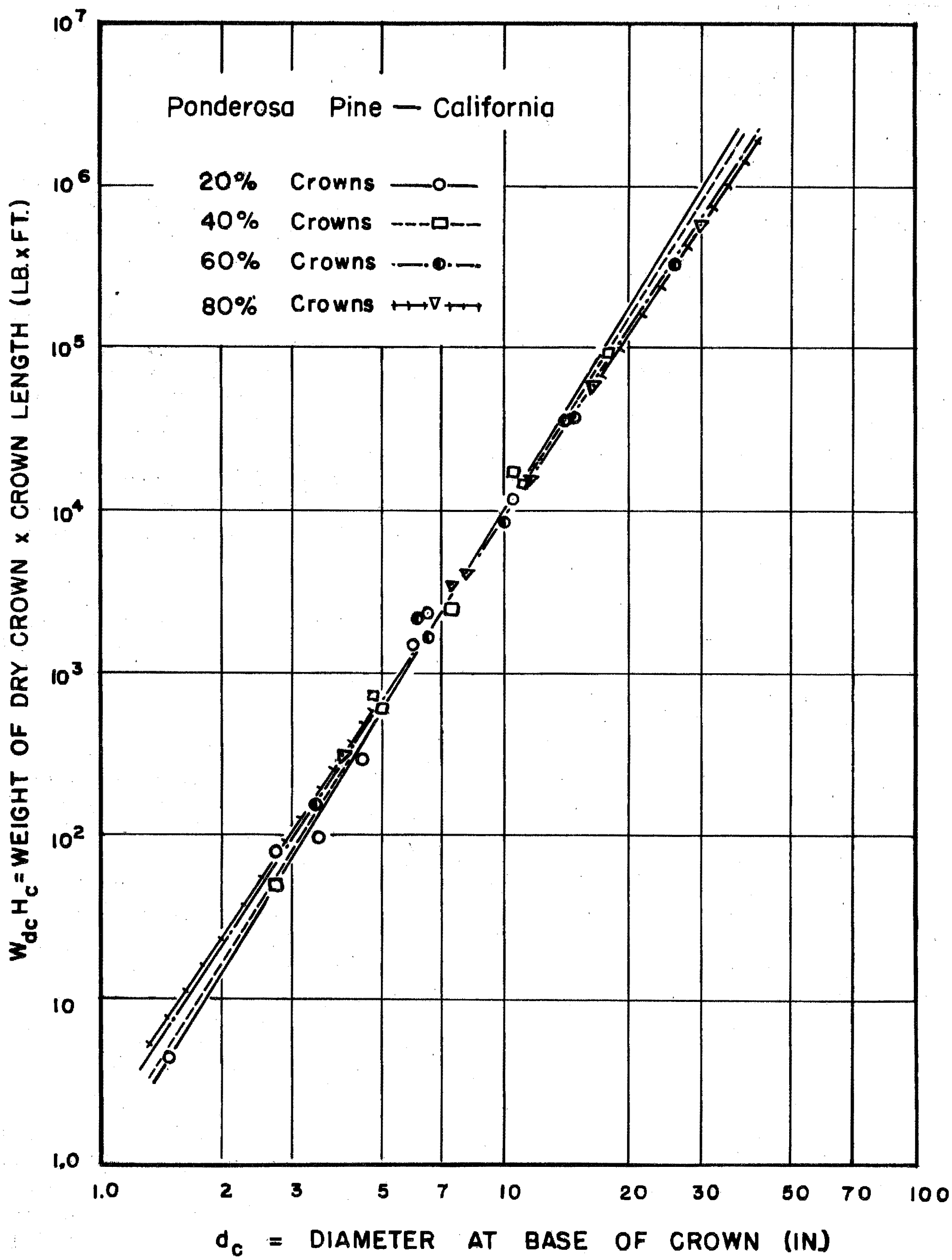

Figure 6.--Relations between dry crown weight, length, and base of crown stem diameter inside bark by percent crown--ponderosa pine (California)

Table 2.- Relations and statistics of dry crown weight and length to stem diameter at base of crown by percent crown--ponderosa pine (California)

Percent crown	Relation: $W_{dc} \cdot H_c = a(d_c)^b$			
	Constants[a]		Statistical measures	
	a	b	r[b]	S_{yx}[c]
20	0.874	4.091	0.994	32
40	1.079	3.968	0.996	25
60	1.603	3.774	0.998	16
80	1.953	3.688	0.999	7

[a]Both constants highly significant at a 1 percent level of probability.
[b]Coefficient of correlation.
[c]Standard error of estimate (percent).

It is not surprising that the weights of dry crown, branchwood, and foliage times crown length proved significantly related to stem diameter. Stem diameter is related to periodic annual increment[3/] of stem wood and periodic increment is determined by the amount of foliage which is carrying on photosynthesis in that period. Kittredge (14) has shown that amount of foliage is correlated with increment of stem wood. From his studies of several conifer species including white pine, Scotch pine, and Norway spruce he concludes that the relation between leaf weight and stem diameter is applicable to trees of different sizes, crown densities, crown classes, and ages at least up to the age of culmination of growth, and beyond that age for tolerant species in all-aged stands. Few of the trees measured in the present study exceeded 80-90 years, the age of culmination of growth for most conifer species and sites. As branchwood serves as underpinnings for the leaves its weight should be related to both amount of foliage and stem diameter.

3/ The growth in volume for any specified period divided by the number of years in the period.

Table 3.- Statistics for relation dry crown weight and length to stem diameter at base of crown

Species and location	Number of trees	Number of data	Range of data: Base crown stem diameter d_c[a]	Range of data: Crown length H_c	Range of data: Crown weight W_{dc}	Relation: $W_{dc} \cdot H_c = a(d_c)^b$ — Constants[b]: a	Constants[b]: b	Statistical measures: r[c]	Statistical measures: S_{yx}[d]
			-inches-	---feet---	-pounds-				percent
Ponderosa pine (Calif.)	13	36	0.9-36.0	2.2-99.0	0.3-5780	1.138	3.923	0.997	23
Ponderosa pine (Idaho)	3	8	1.4-15.1	3.4-57.0	1.5-590	2.559	3.492	0.994	36
Ponderosa pine (Nevada)	43	43	4.6-12.3	7.6-48.1	23.0-333	3.542	3.230	0.928	36
Sugar pine (Calif.	4	11	0.8-12.5	2.4-41.6	0.4-285	1.811	3.461	0.999	15
Western white pine (Idaho	30	37	1.1-17.6	4.1-102.0	1.0-430	7.450	3.084	0.939	68
Lodgepole pine (Calif.)	4	12	3.8-16.0	10.1-45.6	17.6-909	1.205	3.830	0.976	43
Lodgepole pine (Idaho)	7	20	1.3-8.5	4.6-30.6	1.2-185	2.987	3.624	0.975	41
Loblolly pine (S. Car.)	9	17	4.6-11.6	17.3-21.3	59.4-67	9.109	3.108	0.993	31
White fir (Calif.)	9	14	0.3-24.5	0.8-98.0	0.1-1776	2.771	3.509	0.999	15
Grand fir (Idaho)	3	7	1.0-18.3	3.9-120.0	1.0-1055	4.229	3.625	0.997	35

[a] See Nomenclature, page 95.
[b] Both constants highly significant at a 1 percent level of probability.
[c] Coefficient of correlation.
[d] Standard error of estimate.

(Table 3 continued)

Species and location	Number of trees	Number of data	Range of data			Relation: $W_{dc} \cdot H_c = a(d_c)^b$			
			Base crown stem diameter d_c[a]	Crown length H_c	Crown weight W_{dc}	Constants[b]		Statistical measures	
						a	b	r[c]	S_{yx}[d]
			-inches-	---feet---	-pounds-				percent
Douglas-fir (Calif.)	6	14	0.6-18.5	2.1-87.0	0.3-1102	3.341	3.515	0.995	37
Douglas-fir (Idaho)	20	29	1.1-12.9	4.2-64.0	1.8-334	5.690	3.221	0.949	67
Engelmann spruce (Idaho)	14	30	1.2-21.3	5.6-101.0	1.0-824	7.332	3.190	0.983	51
Western hemlock (Idaho)	14	21	1.1-22.3	6.1-85.0	0.8-530	9.470	2.977	0.972	63
Incense cedar (Calif.)	6	14	0.8-15.5	1.8-57.0	0.3-479	2.579	3.533	0.991	45
Western redcedar (Idaho)	15	22	1.1-12.0	5.2-69.0	1.8-266	5.624	3.320	0.991	30
Western larch (Idaho)	11	32	1.0-14.8	4.6-82.0	1.6-372	8.842	2.908	0.953	63
ALL	211	367	0.3-36.0	0.8-120.0	0.1-5780	4.087	3.340	0.975	67

[a] See Nomenclature, page 95.
[b] Both constants highly significant at a 1 percent level of probability.
[c] Coefficient of correlation.
[d] Standard error of estimate.

Table 4.- Statistics for relation dry branchwood weight and crown length to stem diameter at base of crown

Species and location	Number of trees	Number of data	Range of data: Base crown stem diameter d_c[a]	Range of data: Crown length H_c	Range of data: Branchwood weight W_{db}	Relation: $W_{dc} \cdot H_c = a(d_c)^b$ — Constants[b]: a	Constants[b]: b	Statistical measures: r[c]	Statistical measures: S_{yx}[d]
			-inches-	---feet---	-pounds-				percent
Ponderosa pine (Calif.)	13	36	0.8-30.0	2.2-99.0	0.1-5007	0.392	4.223	0.997	26
Sugar pine (Calif.)	4	11	0.8-12.5	2.4-41.6	0.1-199	0.543	3.855	1.000	10
Lodgepole pine (Calif.)	4	12	3.8-16.0	9.2-45.6	8.0-680	0.438	4.111	0.977	46
Loblolly pine (S. Car.)	9	17	0.6-11.6	2.2-39.9	0.3-386	3.098	3.448	0.994	34
White fir (Calif.)	9	10	0.3-24.5	0.8-98.0	0.1-1255	0.809	3.782	0.999	14
Douglas-fir (Calif.)	6	13	0.6-18.5	2.1-87.0	0.1-885	1.002	3.884	0.996	34
Engelmann spruce (Idaho)	7	20	1.2-16.8	7.0-81.0	0.6-595	3.520	3.392	0.991	36
Incense cedar (Calif.)	6	13	0.8-15.5	1.8-57.0	0.1-310	0.796	3.765	0.990	46
Western larch (Idaho)	7	20	1.0-14.8	4.6-76.3	0.7-272	4.960	3.213	0.981	45
ALL	65	152	0.3-30.0	0.8-99.0	0.1-5007	1.146	3.782	0.991	43

[a] See Nomenclature, page 95.
[b] Both constants highly significant at a 1 percent level of probability.
[c] Coefficient of correlation.
[d] Standard error of estimate.

Table 5.- Statistics for relation dry foliage weight and crown length to stem diameter at base of crown

Species and location			Range of data: Base crown stem diameter d_c[a]	Range of data: Crown length H_c	Range of data: Foliage weight W_{df}	Relation: $W_{dc} \cdot H_c = a(d_c)^b$ — Constants[b]: a	Constants[b]: b	Statistical measures: r[c]	Statistical measures: S_{yx}[d]
			--inches--	---feet---	-pounds-				percent
Ponderosa pine (Calif.)	13	36	0.8-30.0	2.2-99.0	0.2-774	1.012	3.422	0.993	32
Sugar pine (Calif.)	4	11	0.8-12.5	2.4-41.6	0.3-86	1.301	3.090	0.997	17
Lodgepole pine (Calif.)	4	12	3.8-16.0	9.2-45.6	8.0-229	1.070	3.356	0.967	44
Loblolly pine (S. Car.)	9	17	0.6-11.6	2.2-39.9	0.7-148	6.282	2.737	0.992	30
White fir (Calif.)	9	10	0.3-24.5	0.8-98.0	0.3-521	2.226	3.232	0.998	20
Douglas-fir (Calif.)	6	13	0.6-18.5	2.1-87.0	0.4-217	2.524	3.101	0.989	45
Engelmann spruce (Idaho)	7	20	1.2-16.8	7.0-81.0	1.0-229	6.310	2.922	0.986	38
Incense cedar (Calif.)	6	13	0.8-15.5	1.8-57.0	0.2-169	2.509	3.186	0.986	48
Western larch (Idaho)	7	20	1.0-14.8	4.6-76.3	0.9-100	6.748	2.645	0.976	42
ALL	65	152	0.3-30.0	0.8-99.0	0.2-774	2.870	3.042	0.975	59

[a] See Nomenclature, page 95.
[b] Both constants highly significant at a 1 percent level of probability.
[c] Coefficient of correlation.
[d] Standard error of estimate.

Crown Class

As often as possible young dominant trees conforming to crown class I of Dunning (12) were selected for a given stand; however, an adequate range in diameter classes was also a criterion for tree selection. Therefore, some individuals necessarily were smaller trees in a stand of larger trees, and such trees should represent higher crown classes. Analysis of plotted data for stands where this condition existed showed that relations were applicable alike to dominant and suppressed trees. Similarly, differences in density apparently do not cause serious differences in the trends. The same conclusions were reached by Kittredge (14) and Rothacher (19). This is because normally dominant trees have large crowns and large stem diameter base of crown, whereas overtopped trees have small crowns and small stem diameter.

Effect of Site

The influence of site quality on the relation for crown is conflicting in the available data. Ponderosa pine on poor site (V) in Nevada estimates lower than either of the two better sites (California, site II, and Idaho, site III). The latter two sites are significantly different between themselves whereas the Nevada regression is similar to Idaho but not California. Considering all three sites, the better the site the greater the crown weight times length for diameters above 7 inches. (See figure 7 and table 3) On the other hand lodgepole pine is exactly the opposite. The equation for this species on lower site (III) in Idaho estimates significantly higher than better site (II) in California for all stem diameters. Douglas-fir agrees with ponderosa pine in that the equation for lower site (III) estimates significantly lower than better site (II) from California for diameters above 5 inches. Two statistical tests--significance of the difference between regression coefficients and significance of the difference between intercepts--were used to determine differences between equations.

Age should have no effect on the trends except for the poor site Nevada ponderosa pines which averaged about 160 years of age. Although poor site Nevada trees are much older no tendency to stag-headedness was noticeable and they follow the progressive decrease in weight with decrease in site exhibited by the other two ponderosa pine stands. Other species were below 80 years old with about the same range in ages for all stands. Burger (8) in Switzerland investigated Scotch pine and Norway spruce from different elevations but of the same age. He found that constants are nearly the same for stands of 1300 and 6300 feet elevation while the slopes are distinctly lower for a stand at the intermediate elevation of 3500 feet. Elevations correspond to site. For Norway spruce, stands at lower elevations tend to have higher slopes. Thus the effect of site on the relation for crown appears to vary with species and no general statements can be made at this time.

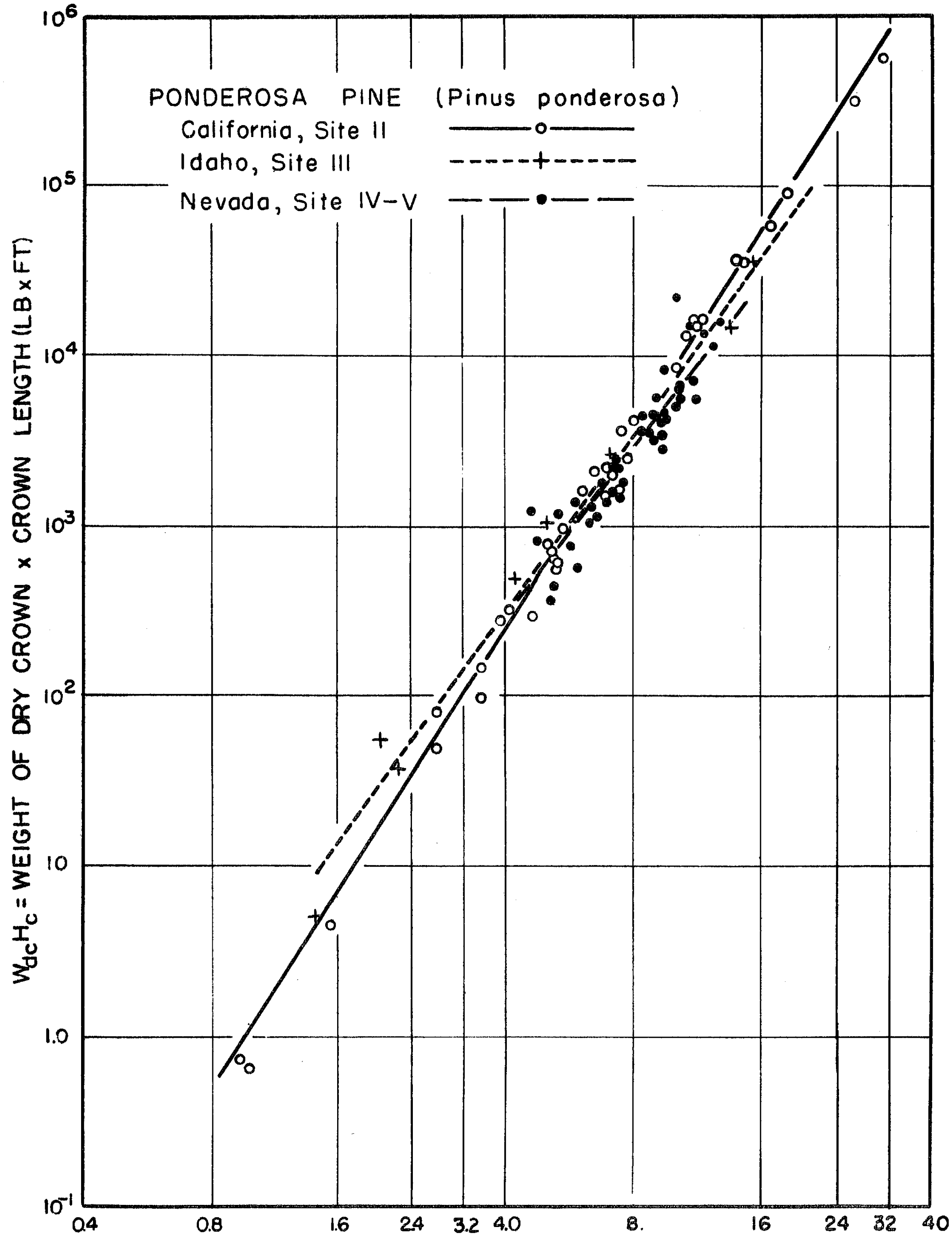

Figure 7.--Relations between dry crown weight, length, and base of crown stem diameter inside bark--ponderosa pine, site II, California; site III, Idaho; site IV-V, Nevada

As only one site was sampled for the other 10 species, crown weight times length variation with site for these species remains an open question.

Species Similarities

An attempt was made to establish similarities of the crown relation by genus, species, site, or silvical characteristics. This might allow certain groupings which would serve as a key to weights of crowns of foreign species or indigenous species not yet analyzed. Ability to predict crown characteristics of any given conifer species is essential to development of a tree breakage prediction system of world-wide applicability.

Visual comparison of regression lines for the crown relations given in figures 8 and 9 shows a marked parallelism among all species and sites. The trends are so similar that relations were plotted in two arbitrary groups on separate graphs to avoid confusion. Grand fir estimates highest and sugar pine lowest for diameters above 8 inches. However, equation constants for most species were demonstrated statistically to be significantly different from those for the average regression line calculated by combining all species and sites (see table 3). Therefore it was necessary to test for differences between relations for successive species pairs to determine species similarities for grouping purposes. Groupings indicated and equation constants are presented in table 6 together with silvical characteristics for each component species. Crown weight times length for an average base of crown stem diameter of 12 inches was calculated for each group (see table 6). Species analyzed for effect of site were included but ponderosa pine and grand fir from Idaho were omitted for lack of data.

Comparison of the silvical characteristics of component species in each group fails to reveal any firm basis for placing species not yet analyzed. For instance, tolerance does not appear necessarily to be correlated with crown weight times length, as witness group 6, table 6 which contains Douglas-fir and lodgepole pine, nearly the extremes in tolerance. Likewise, botanical characteristics failed to explain listed groups. The genus Pinus, for instance, is scattered throughout the groups. It seems most illogical that crown weight of lodgepole pine from California (group 2), a slim-crowned tree and usually regarded as a light-crowned, should be more nearly similar to heavy-crowned ponderosa pine than to lodgepole pine from Idaho (group 6). It is true, however, that northern-grown lodgepole pine (Idaho) is generally regarded as lighter crowned than the same species grown in California. Groups 7 and 8, respectively western larch and sugar pine, agree with accepted rankings as both are considered to have light crowns compared to other conifer species.

Neither needle length nor the number of years that needles persist appears to explain the indicated groupings.

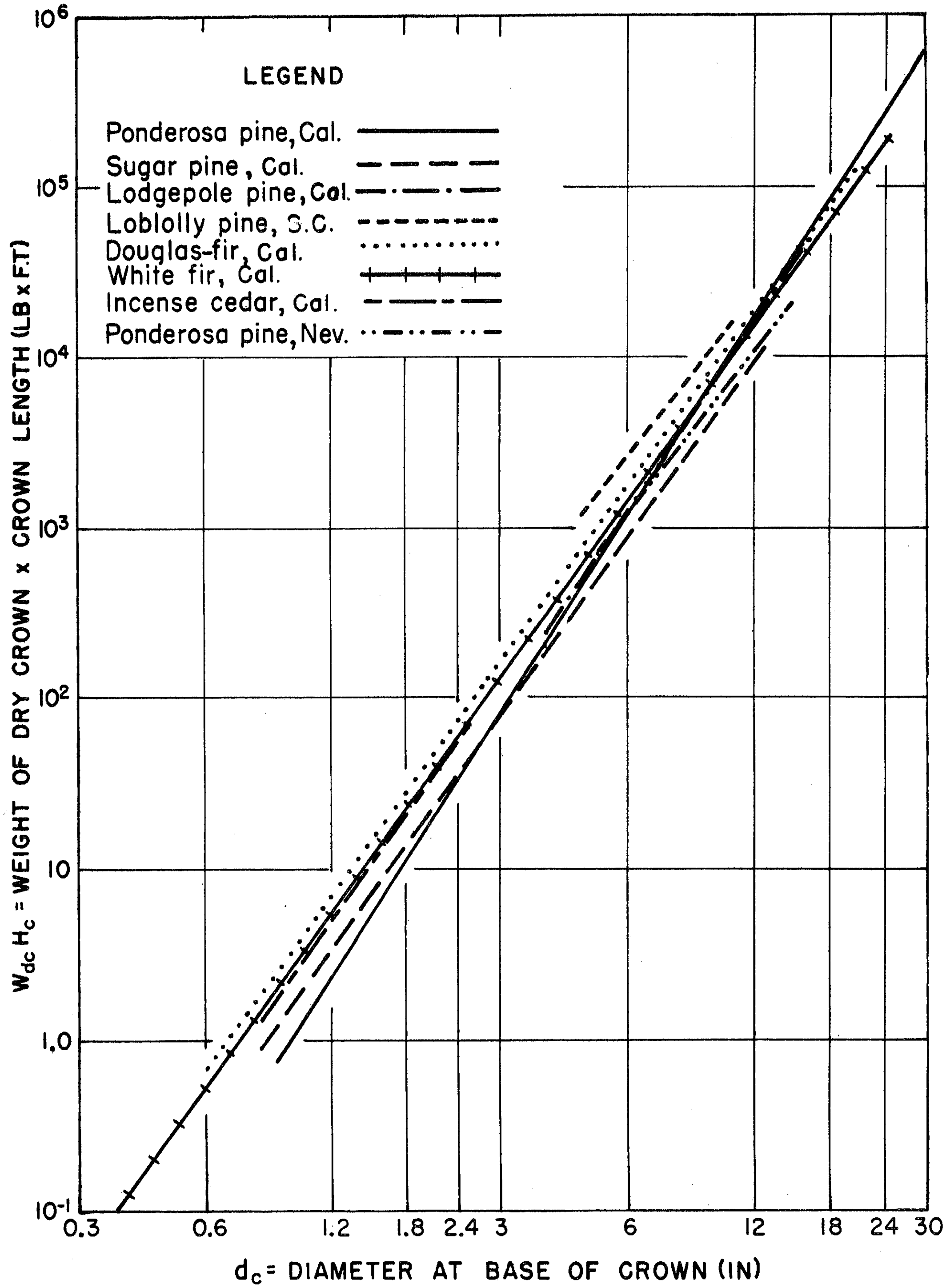

Figure 8.--Relations between dry crown weight, length, and base of crown stem diameter inside bark--six California conifer species and loblolly pine from So. Carolina

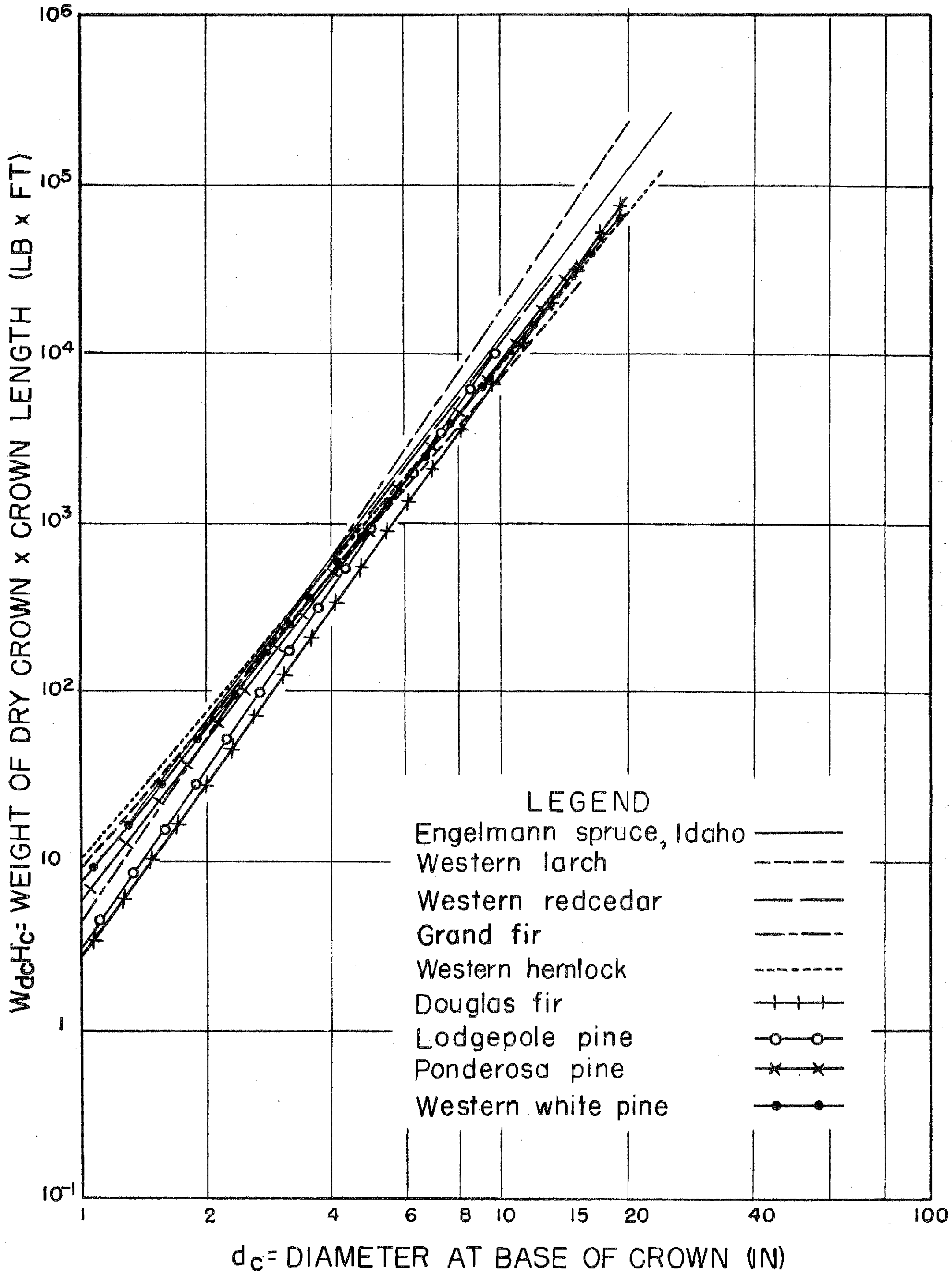

Figure 9.--Relations between dry crown weight, length, and base of crown stem diameter inside bark--nine Idaho conifer species

Table 6.- Statistical grouping of species together with comparative silvical characteristics, equation constants, and errors of estimate

Group No.	Species	Silvical characteristics: Relative tolerance of shading[a]	Silvical characteristics: Site class	Silvical characteristics: Average length of needles	Silvical characteristics: Average time needles persist	Relation: $W_{dc} \cdot H_c = a(d_c)^b$ — Constants[b]: a	Constants[b]: b	Statistical measures: r[c]	Statistical measures: S_{yx}[d]	$W_{dc} \cdot H_c$ (for d_c = 12 in.)
				-inches-	-years-				percent	-lb. x ft.-
1	Western redcedar (Ida.)	3	III	1/4	3	5.168	3.309	0.971	51	19,200
	Douglas-fir (Ida.)	7	III	1	8					
2	Ponderosa pine (Calif.)	10	II	8	3	1.130	3.911	0.995	29	18,800
	Lodgepole pine (Calif.)	14	II	2	7					
3	Engelmann spruce (Ida.)	1	III	1	3	7.460	3.123	0.967	60	17,500
	Western white pine(Ida.)	9	II	3	3-4					
4	White fir (Calif.)	2	II	2-1/2	7	2.700	3.514	0.997	32	16,800
	Incense cedar (Calif.)	5	II	[e]1/8-1/2	2-3					
5	Western hemlock (Ida.)	4	III	5/8	4	9.762	2.997	0.984	50	16,700
	Loblolly pine (S. Car.)	8	II	7-1/2	3					
6	Douglas-fir (Calif.)	6	II	1	8					
	Ponderosa pine (Nev.)	11	IV-V	6	3	2.793	3.284	0.970	55	13,300
	Lodgepole pine (Ida.)	15	III	2	7					
7	Western larch (Ida.)	13	III	1-1/2	[f]1	11.171	2.798	0.953	63	11,700
8	Sugar pine (Calif.)	12	III	3-3/4	2-3	1.811	3.461	0.999	15	9,800

[a]Designation 1 most tolerant (1, pp. 233-234).
[b]Both constants highly significant at a 1 percent level of probability.
[c]Coefficient of correlation.
[d]Standard error of estimate.
[e]1/8 inch on the ultimate lateral branchlets to 1/2 inch on leading shoots.
[f]Deciduous.

As no suitable botanical or silvical basis for placing other species is immediately apparent, crown weight times length should be estimated from the combined regression calculated from all data (see table 3).

The relations for the crown components--dry branchwood and dry foliage--were not analyzed in such detail. However, comparison of relations for each species, as shown in Appendix B, figures B-18 to B-26 and B-27 to B-35 respectively, indicates marked parallelism, and reveals certain interesting tree characteristics. For all species foliage contributes more to total crown weight than branchwood does in the young tree below three to six inches diameter. From this size on, however, branchwood makes up the greater part of total crown weight. Examination of the foliage weight curves among species reveals that the foliage of incense cedar, Engelmann spruce, western hemlock, white fir, and to a lesser extent, Douglas-fir consistently forms a larger proportion of the total crown weight than does foliage. This is consistent with observations of these shade-tolerant species which indicate thick clumps of needles growing well back on relatively thin branches.

Not only does branchwood become an increasingly greater contributor to total crown weight with age for all species, but for certain species branchwood becomes a greater relative contributor. Two examples are California ponderosa pine and loblolly pine. Branches thicken at a relatively early age. In general, foliage weights indicated tend to be more in agreement with accepted rankings than total crown weights; however this may be due to the fact that much more work has been done on this important crown component.

Pending more detailed analysis, weight of branchwood and foliage for unfamiliar species should be estimated from the relations combining all species which are given in tables 4 and 5 respectively.

Averages for Selected Cover Types

Current plans envision application of the results of this study on a stand or cover-type basis. However, at the present time, over 250 separate natural forest cover types are recognized in North America alone (22), most of them composed of more than one species. Obviously with the limited number of data available from this study, crown weight times length relations for only a few of the more important types can be specified. Constants for the crown weight relations for 11 selected American cover types are given in table 7. Relations for individual species analyzed but not appearing in this table may be obtained from table 3. Relations for other multiple-species cover types composed of two or more of the species analyzed might be fabricated by weighting by relative abundance. Similar combined relations for several species may be prepared for weights of crown components--dry branchwood and dry foliage--by a similar procedure.

Table 7.- Constants for estimating weight of dry crown for groupings of species and sites corresponding to 11 selected American forest cover types[a]

Cover type	Species composition	Site class	Relation: $W_{dc} \cdot H_c = a(d_c)^b$		
			Equation constants		Coefficient of correlation
			a	b	
Mixed conifer (California)	Ponderosa pine Sugar pine Douglas-fir White fir Incense cedar	II II II II II	2.146	3.605	0.994
Ponderosa pine (California)	Nearly pure ponderosa pine	II	1.138	3.923	0.997
Lodgepole pine (California)	Nearly pure lodgepole pine	II	1.205	3.830	0.976
Douglas-fir (California)	Nearly pure Douglas-fir	II	3.341	3.515	0.995
Larch, Douglas-fir (northern interior)	Western larch[b] Douglas-fir	III III	8.244	3.010	0.955
Ponderosa pine, larch, Douglas-fir (northern interior)	Ponderosa pine[b] Western larch Douglas-fir	III III III	6.409	3.123	0.961
Grand fir, larch, Douglas-fir (northern interior)	Grand fir[b] Western larch Douglas-fir	III III III	6.756	3.137	0.963
Western white pine (northern interior)	Predominantly western white pine[b]	II	7.450	3.084	0.939
Lodgepole pine (northern interior)	Predominantly lodgepole pine[b]	III	2.987	3.627	0.975
Ponderosa pine (Nevada)	Nearly pure ponderosa pine	IV-V	3.542	3.230	0.928
Loblolly pine (southern forest)	Nearly pure loblolly pine	II	9.109	3.108	0.993

[a]See (22).
[b]Western redcedar, Engelmann spruce, and western hemlock usually appear as minor elements in these types if at all.

CONCLUSIONS

1. Equations have been developed for estimating weight of dry crown, dry branchwood, and dry foliage of individual trees of 17 conifer species-sites. The estimating equation is of the form $W \cdot H_c = a(d_c)^b$ where (W) is weight of dry crown, branchwood, or foliage; (H_c) is length of crown; and (d_c) is stem diameter at base of crown.

2. The same relation for weight of crown holds for both the top of a large tree and a full-crowned small tree, i.e., geometry is the same.

3. Variation of crown class has no effect on weight of crown relation.

4. Contrary to popular belief, for species studied, high shade-tolerance does not necessarily indicate heavy crown. Neither genus, needle length, nor the length of time needles persist furnish a clue to relative weight of crown.

5. Weight of crown for species not represented can best be estimated from the equation

$$W_{dc} \cdot H_c = 4.09 \ (d_c)^{3.34}$$

6. It is recommended that weights of crown components for species not represented can best be estimated from the equations

$$W_{db} \cdot H_c = 1.15 \ (d_c)^{3.78} \quad \text{for branchwood}$$

and

$$W_{df} \cdot H_c = 2.87 \ (d_c)^{3.04} \quad \text{for foliage}$$

7. Weight of crown decreases with decreasing site class for ponderosa pine. Among ponderosa pine, lodgepole pine, and Douglas-fir this order is not consistent. Age does not appear to affect the weights.

8. For all conifer species the branchwood to foliage ratio exceeds 1.0 for stem diameters at base of crown greater than 5 inches.

APPENDIX A

PHYSICAL CHARACTERISTICS OF SAMPLE TREES

Table A-1.- Physical characteristics of sample trees[a]

Tree No.	Species	d_{bh}	H_o	Age	Crown[b]	H_c	d_c	W_{dc}	W_{db}	W_{df}
		-inches-	-feet-	-years-	-percent-	-feet-	-inches-		-------pounds-------	
1	Ponderosa pine	9.0	38.3	--	20	7.7	3.5	13.0	6.0	7.0
					40	15.3	5.0	40.0	21.0	19.0
					60	23.0	6.5	73.0	42.0	31.0
					80	30.7	7.5	117.0	75.0	42.0
2	Ponderosa pine	9.5	41.3	40	20	8.2	2.8	10.0	4.0	6.0
					40	16.5	4.8	44.0	22.0	22.0
					60	24.7	6.2	88.0	52.0	36.0
					80	33.0	8.0	125.0	83.0	42.0
3	Ponderosa pine	5.0	18.1	43	20	3.6	1.5	1.2	0.5	0.8
					40	7.2	2.8	7.0	3.5	3.5
					60	10.7	3.5	15.0	8.5	6.5
					80	14.3	4.0	22.0	13.2	8.8
4	Ponderosa pine	15.0	58.7	54	20	11.8	4.5	25.0	12.0	13.0
					40	23.5	7.5	108.0	60.0	48.0
					60	35.3	10.0	251.0	178.0	73.0
					80	47.0	11.5	333.0	248.0	85.0
5	Ponderosa pine	22.8	90.0	56	20	18.0	6.0	88.0	52.0	36.0
					40	36.0	11.2	427.0	327.0	100.0
					60	54.0	14.5	702.0	550.0	152.0
					80	72.0	16.8	809.0	642.0	167.0
6	Ponderosa pine	37.0	124.0	--	20	24.7	10.5	500.0	357.0	143.0
					40	49.5	18.0	1824.0	[c]1475.0	[c]347.0
					60	74.2	25.5	4200.0	[c]3569.0	[c]631.0
					80	99.0	30.0	5781.0	[c]5007.0	[c]774.0

[a]For definition of symbols see Nomenclature, page 95.
[b]Percents refer to total height of tree; one third, half, etc., refer to total length of crown.
[c]Branch and foliage weights from samples.

Table A-1 (continued)

Tree No.	Species	d_{bh}	H_o	Age	Crown[b]	H_c	d_c	W_{dc}	W_{db}	W_{df}
		-inches-	-feet-	-years-	-percent-	-feet-	-inches-	-------pounds-------		
7	Ponderosa pine	--	--	--	Half	14.0	5.0	48.2	25.9	22.3
					Full	20.0	6.8	103.0	62.8	40.2
8	Ponderosa pine	--	--	--	Half	12.4	5.0	44.3	23.7	20.6
					Full	19.4	7.2	89.1	55.4	33.7
9	Ponderosa pine	--	--	--	Half	10.2	3.9	27.4	12.6	14.8
					Full	14.6	5.4	66.1	36.1	30.0
10	Ponderosa pine	--	--	--	Full	2.4	0.8	0.4	0.1	0.3
11	Ponderosa pine	--	--	--	Full	2.3	1.0	0.3	0.1	0.2
12	Ponderosa pine	--	--	--	Full	2.2	0.9	0.4	0.1	0.2
13	Ponderosa pine	20.3	92.0	199	20	18.4	6.5	126.0	[c]97.0	[c]29.0
					40	36.8	10.8	482.0	[c]395.0	[c]87.0
					60	55.2	14.0	653.0	[c]544.0	[c]109.0
14	Ponderosa pine	6.5	--	--	One third	7.9	2.1	7.2	--	--
					Two thirds	15.8	4.1	31.6	--	--
					Full	23.8	5.4	42.4	--	--
15	Ponderosa pine	20.0	--	--	One third	19.0	7.2	141.2	--	--
					Two thirds	38.0	13.0	382.2	--	--
					Full	57.0	15.1	589.7	--	--
16	Ponderosa pine	2.5	--	--	One third	3.4	1.4	1.5	--	--
					Two thirds	6.8	2.3	5.6	--	--
17	Ponderosa pine	--	37.5	94	86	32.8	10.0	153.9	--	--
18	Ponderosa pine	--	63.3	195	75	47.6	10.9	115.1	--	--
19	Ponderosa pine	--	35.3	141	80	28.7	6.9	87.8	--	--
20	Ponderosa pine	--	52.8	167	59	31.6	8.8	148.8	--	--

[b]Percents refer to total height of tree; one third, half, etc., refer to total length of crown.
[c]Branch and foliage weights from samples.

Table A-1 (continued)

Tree No.	Species	d_{bh}	H_o	Age	Crown[b]	H_c	d_c	W_{dc}	W_{db}	W_{df}
		-inches-	-feet-	-years-	-percent-	-feet-	-inches-	----------	pounds	----------
21	Ponderosa pine	--	39.1	169	73	28.9	9.4	154.6	--	--
22	Ponderosa pine	--	66.5	117	70	47.0	11.3	328.4	--	--
23	Ponderosa pine	--	55.3	146	71	39.6	9.5	205.0	--	--
24	Ponderosa pine	--	54.5	176	38	21.1	5.8	72.6	--	--
25	Ponderosa pine	--	32.3	133	70	23.1	5.6	32.9	--	--
26	Ponderosa pine	--	32.6	74	87	28.8	7.7	55.0	--	--
27	Ponderosa pine	--	55.2	153	70	39.0	10.5	181.3	--	--
28	Ponderosa pine	--	36.9	136	72	26.9	8.4	142.4	--	--
29	Ponderosa pine	--	41.8	164	70	29.2	9.4	99.8	--	--
30	Ponderosa pine	--	45.4	181	68	30.7	9.0	131.0	--	--
31	Ponderosa pine	--	48.5	225	76	37.0	8.6	83.1	--	--
32	Ponderosa pine	--	43.5	139	72	31.4	7.2	50.7	--	--
33	Ponderosa pine	--	55.8	168	69	38.7	12.1	315.9	--	--
34	Ponderosa pine	--	58.1	167	74	42.9	10.4	145.6	--	--
35	Ponderosa pine	--	60.0	150	67	40.0	9.5	109.5	--	--
36	Ponderosa pine	--	53.0	183	54	28.7	7.6	83.2	--	--
37	Ponderosa pine	--	58.0	167	45	26.3	9.2	134.5	--	--
38	Ponderosa pine	--	39.6	160	54	31.5	7.7	87.0	--	--
39	Ponderosa pine	--	57.1	172	65	37.2	10.0	188.0	--	--
40	Ponderosa pine	--	56.6	158	73	41.5	10.2	138.4	--	--
41	Ponderosa pine	--	50.8	139	82	41.8	10.9	333.3	--	--

[b]Percents refer to total height of tree; one third, half, etc., refer to total length of crown.

Table A-1 (continued)

Tree No.	Species	d_{bh}	H_o	Age	Crown[b]	H_c	d_c	W_{dc}	W_{db}	W_{df}
		-inches-	-feet-	-years-	-percent-	-feet-	-inches-	--------pounds-------		
42	Ponderosa pine	--	59.5	142	81	48.1	12.3	325.1	--	--
43	Ponderosa pine	--	50.1	181	60	29.8	7.9	72.9	--	--
44	Ponderosa pine	--	34.2	140	40	13.6	5.2	80.0	--	--
45	Ponderosa pine	--	27.6	70	60	17.4	6.3	83.0	--	--
46	Ponderosa pine	--	35.9	92	80	29.2	9.0	200.0	--	--
47	Ponderosa pine	--	24.6	190	30	7.6	5.1	60.0	--	--
48	Ponderosa pine	--	34.2	70	50	17.2	6.7	88.0	--	--
49	Ponderosa pine	--	36.6	97	60	22.5	8.5	157.0	--	--
50	Ponderosa pine	--	27.9	83	80	24.0	9.1	145.0	--	--
51	Ponderosa pine	--	31.0	127	40	13.0	5.9	44.0	--	--
52	Ponderosa pine	--	38.9	156	60	24.0	7.0	90.0	--	--
53	Ponderosa pine	--	38.2	82	50	19.3	6.4	60.0	--	--
54	Ponderosa pine	--	32.6	87	50	16.8	5.0	23.0	--	--
55	Ponderosa pine	--	28.3	100	50	14.2	4.6	96.0	--	--
56	Ponderosa pine	--	33.1	157	50	16.8	6.2	62.0	--	--
57	Ponderosa pine	--	36.0	167	60	21.6	6.9	90.0	--	--
58	Ponderosa pine	--	33.3	85	80	26.4	8.4	170.0	--	--
59	Ponderosa pine	--	34.1	133	40	13.6	4.8	65.0	--	--
60	Sugar pine	11.0	45.0	--	20	9.0	3.2	11.1	5.6	5.6
					Full	15.7	5.4	33.1	22.0	11.1
					40	16.8	5.5	33.1	22.0	11.1
					60	25.8	7.5	75.2	[c]50.8	24.4
					80	34.8	9.0	97.4	[c]68.5	28.9

[b]Percents refer to total height of tree; one third, half, etc., refer to total length of crown.
[c]Branch and foliage weights from samples.

Table A-1 (continued)

Tree No.	Species	d_{bh}	H_o	Age	Crown[b]	H_c	d_c	W_{dc}	W_{db}	W_{df}
		-inches-	-feet-	-years-	-percent-	-feet-	-inches-	--------pounds--------		
61	Sugar pine	17.5	52.0	--	20	10.4	3.8	14.0	[c]7.0	7.0
					40	20.8	7.2	100.0	[c]65.0	35.0
					60	31.2	10.0	213.0	[c]144.0	69.0
					80	41.6	12.5	285.0	[c]199.0	86.0
62[d]	Sugar pine	--	--	--	Half	9.0	3.2	11.1	5.6	5.6
					Full	15.7	5.4	33.1	22.0	11.1
63	Sugar pine	--	--	--	Full	2.4	0.8	0.4	0.1	0.3
64	Western white pine	7.8	--	--	One third	18.3	2.8	10.2	--	--
					Two thirds	36.6	5.1	30.5	--	--
					Full	55.0	6.4	41.5	--	--
65	Western white pine	19.0	--	--	One third	32.1	6.1	70.5	--	--
					Two thirds	64.2	10.5	214.1	--	--
					Full	96.3	12.5	313.0	--	--
66	Western white pine	10.0	--	--	One third	21.3	3.4	22.2	--	--
					Two thirds	42.6	4.0	62.7	--	--
					Full	63.9	8.2	111.6	--	--
67	Western white pine	2.2	--	--	One third	4.1	1.1	1.0	--	--
					Two thirds	8.2	1.7	3.3	--	--
68	Western white pine	14.1	--	--	Full	73.0	9.2	77.4	--	--
69	Western white pine	15.5	--	--	Full	71.0	11.1	97.4	--	---
70	Western white pine	15.3	--	--	Full	62.0	9.0	100.5	--	--
71	Western white pine	14.7	--	--	Full	59.0	9.1	99.5	--	--
72	Western white pine	14.5	--	--	Full	46.0	8.0	90.2	--	--
73	Western white pine	15.1	--	--	Full	52.0	8.3	93.3	--	--
74	Western white pine	12.8	--	--	Full	64.0	9.6	92.3	--	--

[b]Percents refer to total height of tree; one third, half, etc., refer to total length of crown.
[c]Branch and foliage weights from samples.
[d]Tree No. 62 is top of and integrated into Tree No. 60; 20 equals half.

Table A-1 (continued)

Tree No.	Species	d_{bh}	H_o	Age	Crown[b]	H_c	d_c	W_{dc}	W_{db}	W_{df}
		-inches-	-feet-	-years-	-percent-	-feet-	-inches-		-pounds-	
75	Western white pine	13.7	--	--	Full	66.0	10.3	115.9	--	--
76	Western white pine	19.1	--	--	Full	61.0	11.3	103.6	--	--
77	Western white pine	13.6	--	--	Full	74.0	11.1	198.5	--	--
78	Western white pine	13.4	--	--	Full	63.0	8.3	124.6	--	--
79	Western white pine	93.0	--	--	Full	54.0	7.0	40.0	--	--
80	Western white pine	16.4	--	--	Full	65.0	12.3	145.6	--	--
81	Western white pine	12.0	--	--	Full	72.0	9.4	99.5	--	--
82	Western white pine	14.0	--	--	Full	81.0	10.5	175.4	--	--
83	Western white pine	12.0	--	--	Full	70.0	7.9	99.0	--	--
84	Western white pine	12.5	--	--	Full	65.0	6.6	54.9	--	--
85	Western white pine	12.4	--	--	Full	75.0	7.7	79.0	--	--
86	Western white pine	18.2	--	--	Full	84.0	12.2	261.0	--	--
87	Western white pine	14.2	--	--	Full	74.0	10.4	113.8	--	--
88	Western white pine	14.8	--	--	Full	74.0	11.1	157.4	--	--
89	Western white pine	18.1	--	--	Full	84.0	10.7	266.2	--	--
90	Western white pine	15.3	--	--	Full	61.0	7.3	177.4	--	--
91	Western white pine	22.6	--	--	Full	102.0	17.6	430.2	--	--
92	Western white pine	18.6	--	--	Full	71.0	11.6	187.2	--	--
93	Western white pine	12.0	--	--	Full	55.0	8.2	69.2	--	--

[b]Percents refer to total height of tree; one third, half, etc., refer to total length of crown.

Table A-1 (continued)

Tree No.	Species	d_{bh}	H_o	Age	Crown[b]	H_c	d_c	W_{dc}	W_{db}	W_{df}
		-inches-	-feet-	-years-	-percent-	-feet-	-inches-	-------pounds-------		
94	Lodgepole pine	10.8	46.0	--	20	9.2	4.2	16.0	8.0	8.0
					Half	11.9	4.2	17.6	8.3	9.4
					Full	16.9	5.4	42.8	24.8	18.0
					40	18.4	5.8	64.0	39.0	24.9
					60	27.6	9.0	134.0	[c]92.1	41.8
					80	36.8	9.2	192.0	[c]136.6	55.1
95	Lodgepole pine	17.8	57.0	52	20	11.4	4.2	52.0	26.0	26.0
					40	22.8	8.3	244.0	156.0	88.0
					60	34.2	12.1	610.0	444.0	166.0
					80	45.6	16.0	909.0	680.0	229.0
96	Lodgepole pine	--	--	--	Half	10.1	3.8	22.5	13.7	8.8
					Full	17.1	6.0	58.2	16.2	16.2
97[e]	Lodgepole pine	--	--	--	Half	11.9	4.2	17.6	8.3	9.4
					Full	16.9	5.4	42.0	24.8	18.0
98	Lodgepole pine	13.7	--	--	One third	10.2	3.1	27.5	--	--
					Two thirds	20.4	6.2	89.0	--	--
					Full	30.6	8.5	184.8	--	--
99	Lodgepole pine	10.6	--	--	One third	9.2	2.8	6.5	--	--
					Two thirds	18.5	5.6	47.0	--	--
					Full	27.8	6.4	92.8	--	--
100	Lodgepole pine	11.5	--	--	One third	5.7	3.5	36.0	--	--
					Two thirds	11.4	4.1	84.7	--	--
					Full	17.2	5.4	120.0	--	--
101	Lodgepole pine	10.8	--	--	One third	6.0	2.9	32.0	--	--
					Two thirds	12.0	4.4	64.8	--	--
					Full	18.0	5.1	90.6	--	--

[b] Percents refer to total height of tree; one third, half, etc., refer to total length of crown.
[c] Branch and foliage weights from samples.
[e] Tree No. 97 is top of and integrated into Tree No. 94.

Table A-1 (continued)

Tree No.	Species	d_{bh}	H_o	Age	Crown[b]	H_c	d_c	W_{dc}	W_{db}	W_{df}
		-inches-	-feet-	-years-	-percent-	-feet-	-inches-	-------pounds-------		
102	Lodgepole pine	13.8	--	--	One third	8.5	3.6	20.0	--	--
					Two thirds	17.0	5.5	88.7	--	--
					Full	25.6	6.6	102.9	--	--
103	Lodgepole pine	10.8	--	--	One third	8.8	3.1	21.0	--	--
					Two thirds	17.6	5.6	95.4	--	--
					Full	26.5	6.9	125.4	--	--
104	Lodgepole pine	2.9	--	--	One third	4.6	1.3	1.2	--	--
					Two thirds	9.3	1.8	4.5	--	--
105	Loblolly pine	4.9	42.0	19	20	8.4	1.8	7.3	2.5	4.8
					40	16.8	2.6	14.1	6.7	7.4
106	Loblolly pine	20.3	96.6	45	20	21.0	7.0	156.6	[c]103.5	53.1
					40	39.9	11.6	534.1	[c]386.2	147.9
107	Loblolly pine	15.2	72.3	28	20	17.0	5.4	110.6	[c]66.6	44.0
					40	30.9	9.9	358.9	[c]263.5	95.4
					50	37.8	10.8	432.2	[c]324.7	107.5
108	Loblolly pine	11.4	74.3	25	25	18.2	4.9	69.4	[c]38.1	31.3
					35	26.2	6.2	134.4	[c]182.3	52.7
109	Loblolly pine	13.4	73.5	31	20	14.7	5.8	52.0	[c]29.8	22.2
					40	29.4	6.8	161.8	[c]115.2	46.6
110	Loblolly pine	1.5	11.5	12	20	2.2	0.6	1.0	0.3	0.7
					40	4.5	1.1	2.4	0.8	1.6
					60	6.8	1.4	3.4	1.4	2.0
111	Loblolly pine	10.8	64.9	--	Full	21.3	5.1	59.4	37.8	21.6
112	Loblolly pine	8.0	42.4	--	Full	19.1	4.6	63.8	41.5	22.3
113	Loblolly pine	10.2	72.4	--	Full	17.3	4.8	67.4	41.3	26.1

[b]Percents refer to total height of tree; one third, half, etc., refer to total length of crown.
[c]Branch and foliage weights from samples.

Table A-1 (continued)

Tree No.	Species	d_{bh}	H_o	Age	Crown[b]	H_c	d_c	W_{dc}	W_{db}	W_{df}
		-inches-	-feet-	-years-	-percent-	-feet-	-inches-		-------pounds-------	
114	White fir	30.0	122.5	68	20	25.5	7.2	128.4	64.3	64.1
					40	49.0	14.0	680.0	424.0	256.0
					60	73.5	20.2	1289.0	[c]877.0	412.0
					80	98.0	24.5	1776.0	[c]1255.0	521.0
115	White fir	17.7	82.0	39	20	16.4	4.8	37.4	14.8	22.6
					40	32.8	9.0	186.0	[c]97.2	88.8
					60	49.2	12.2	390.0	[c]227.0	162.7
					80	65.6	14.2	571.0	[c]349.0	222.0
116	White fir	--	--	--	Half	12.0	3.8	26.5	9.3	17.2
					Full	17.0	5.2	50.8	20.7	30.1
117	White fir	--	--	--	Half	10.5	4.2	32.3	12.4	19.9
					Full	15.4	5.5	69.6	31.1	38.5
118	White fir	--	--	--	Full	1.6	0.7	0.6	0.2	0.4
119	White fir	--	--	--	Full	1.9	0.7	0.4	0.1	0.3
120	White fir	--	--	--	Full	2.3	0.8	0.6	--	--
121	White fir	--	--	--	One third	0.8	0.3	0.1	--	--
					Two thirds	1.5	0.6	0.2	--	--
					Full	2.2	0.7	0.4	--	--
122	White fir	--	--	--	Full	4.6	1.6	3.0	--	--
123	Grand fir	24.7	--	--	One third	40.0	11.0	449.5	--	--
					Two thirds	80.0	13.4	926.5	--	--
					Full	120.0	18.3	1054.6	--	--
124	Grand fir	2.3	--	--	One third	3.9	1.0	1.0	--	--
					Two thirds	7.9	1.9	4.3	--	--
125	Grand fir	6.2	--	--	One third	11.1	2.1	6.2	--	--
					Two thirds	22.2	4.2	53.2	--	--

[b]Percents refer to total height of tree; one third, half, etc., refer to total length of crown.
[c]Branch and foliage weights from samples.

Table A-1 (continued)

Tree No.	Species	d_{bh}	H_o	Age	Crown[b]	H_c	d_c	W_{dc}	W_{db}	W_{df}
		-inches-	-feet-	-years-	-percent-	-feet-	-inches-	-------pounds-------		
126	Douglas-fir	12.5	63.5	62	20	12.8	5.0	24.0	15.0	9.0
					40	25.5	7.0	107.0	[c]72.0	35.0
					60	38.2	9.5	256.0	[c]183.0	73.0
					80	51.0	10.5	355.0	[c]259.0	96.0
127	Douglas-fir	11.0	108.8	91	20	21.8	5.8	80.0	48.0	32.0
					40	43.5	11.0	370.0	[c]271.0	99.0
					60	65.2	16.0	933.0	[c]741.0	192.0
					80	87.0	18.5	1102.0	[c]885.0	217.0
128	Douglas-fir	--	--	--	Half	11.8	3.1	16.4	7.5	8.9
					Full	17.1	4.4	44.6	21.5	23.1
129	Douglas-fir	--	--	--	Half	11.2	2.8	10.6	4.4	6.2
					Full	15.2	3.8	27.9	12.8	15.1
130	Douglas-fir	--	--	--	Full	2.1	0.6	0.4	0.1	0.4
131	Douglas-fir	--	--	--	Full	2.1	0.6	0.3	--	--
132	Douglas-fir	6.0	--	--	One third	9.5	1.9	7.8	--	--
					Two thirds	19.0	4.0	43.4	--	--
					Full	28.6	4.7	60.5	--	--
133	Douglas-fir	2.6	--	--	One third	4.2	1.1	1.8	--	--
					Two thirds	8.4	1.9	4.1	--	--
134	Douglas-fir	17.8	--	--	One third	18.3	5.5	73.0	--	--
					Two thirds	36.6	9.0	217.8	--	--
					Full	55.0	11.0	318.8	--	--
135	Douglas-fir	18.8	--	--	One third	18.0	6.0	75.0	--	--
					Two thirds	36.0	9.8	189.3	--	--
					Full	54.0	11.9	334.2	--	--
136	Douglas-fir	14.5	--	-	Full	44.0	9.2	139.0	--	--

[b]Percents refer to total height of tree; one third, half, etc., refer to total length of crown.
[c]Branch and foliage weights from samples.

Table A-1 (continued)

Tree No.	Species	d_{bh}	H_o	Age	Crown[b]	H_c	d_c	W_{dc}	W_{db}	W_{df}
		-inches-	-feet-	-years-	-percent-	-feet-	-inches-	--------pounds--------		
137	Douglas-fir	21.6	--	--	Full	60.0	12.7	347.8	--	--
138	Douglas-fir	14.1	--	--	Full	53.0	9.4	167.2	--	--
139	Douglas-fir	16.7	--	--	Full	53.0	10.2	191.8	--	--
140	Douglas-fir	16.7	--	--	Full	50.0	9.4	249.5	--	--
141	Douglas-fir	15.0	--	--	Full	64.0	10.5	190.4	--	--
142	Douglas-fir	12.3	--	--	Full	56.0	8.8	185.7	--	--
143	Douglas-fir	18.9	--	--	Full	46.0	10.9	211.1	--	--
144	Douglas-fir	17.0	--	--	Full	62.0	11.5	238.3	--	--
145	Douglas-fir	15.9	--	--	Full	54.0	10.6	263.2	--	--
146	Douglas-fir	21.7	--	--	Full	47.0	10.7	234.8	--	--
147	Douglas-fir	17.9	--	--	Full	48.0	10.0	177.4	--	--
148	Douglas-fir	15.3	--	--	Full	44.0	9.1	147.8	--	--
149	Douglas-fir	16.2	--	--	Full	41.0	9.4	167.2	--	--
150	Douglas-fir	19.6	--	--	Full	48.0	12.9	309.2	--	--
151	Douglas-fir	13.2	--	--	One third	12.5	4.1	47.2	--	--
					Two thirds	25.0	6.6	149.4	--	--
					Full	37.6	8.5	220.8	--	--
152	Engelmann spruce	3.1	--	--	One third	5.6	1.4	1.0	--	--
					Two thirds	11.2	2.2	4.8	--	--
153	Engelmann spruce	6.4	--	--	One third	7.7	1.8	7.2	--	--
					Two thirds	15.5	5.7	44.6	--	--
					Full	23.3	6.4	104.8	--	--
154	Engelmann spruce	18.6	--	--	Full	65.0	15.2	519.5	--	--

[b]Percents refer to total height of tree; one third, half, etc., refer to total length of crown.

Table A-1 (continued)

Tree No.	Species	d_{bh}	H_o	Age	Crown[b]	H_c	d_c	W_{dc}	W_{db}	W_{df}
		-inches-	-feet-	-years-	-percent-	-feet-	-inches-	--------pounds--------		
155	Engelmann spruce	14.6	--	--	Full	66.0	10.4	233.4	--	--
156	Engelmann spruce	25.6	--	--	Full	95.0	18.4	470.0	--	--
157	Engelmann spruce	24.4	--	--	Full	101.0	21.3	807.0	--	--
158	Engelmann spruce	15.7	--	--	Full	68.0	11.9	184.6	--	--
159	Engelmann spruce	2.4	17.0	36	Half	7.0	1.2	1.6	0.6	1.0
					Full	13.9	2.2	10.0	4.4	5.6
160	Engelmann spruce	12.8	84.7	102	One third	18.8	4.0	49.1	22.6	26.5
					Two thirds	37.5	6.7	138.4	71.8	66.6
					Full	56.2	8.6	215.7	117.5	98.2
161	Engelmann spruce	24.9	130.0	215	One third	27.0	7.4	283.1	149.8	133.3
					Two thirds	54.0	14.0	481.3	297.6	183.7
					Full	81.0	16.8	544.7	348.2	196.5
162	Engelmann spruce	6.8	36.8	78	One third	10.4	2.3	13.0	6.3	6.7
					Two thirds	20.8	3.9	33.2	17.5	15.7
					Full	31.3	5.1	66.9	37.3	29.6
163	Engelmann spruce	5.8	30.6	79	One third	7.2	1.8	4.7	1.9	2.8
					Two thirds	14.5	3.1	14.4	6.7	7.7
					Full	21.8	4.4	45.8	25.3	20.5
164	Engelmann spruce	11.9	64.1	101	One third	16.2	3.4	41.4	22.2	19.2
					Two thirds	32.5	6.0	130.3	73.6	56.7
					Full	48.8	8.2	193.5	114.7	78.8
165	Engelmann spruce	23.5	108.8	179	One third	23.7	6.4	155.7	106.3	49.4
					Two thirds	47.3	12.9	519.5	373.7	145.8
					Full	71.0	16.4	824.1	594.8	229.3
166	Western hemlock	7.0	--	--	One third	9.0	2.7	12.0	--	--
					Two thirds	18.1	4.3	38.4	--	--
					Full	27.2	5.5	64.6	--	--

[b]Percents refer to total height of tree; one third, half, etc., refer to total length of crown.

Table A-1 (continued)

Tree No.	Species	d_{bh}	H_o	Age	Crown[b]	H_c	d_c	W_{dc}	W_{db}	W_{df}
		-inches-	-feet-	-years-	-percent-	-feet-	-inches-	-------pounds-------		
167	Western hemlock	3.0	--	--	One third	6.1	1.1	0.8	--	--
					Two thirds	12.2	2.0	4.6	--	--
168	Western hemlock	11.5	--	--	One third	24.3	3.8	29.0	--	--
					Two thirds	48.6	7.4	165.0	--	--
					Full	73.0	9.1	273.7	--	--
169	Western hemlock	20.0	--	--	One third	21.6	5.0	52.0	--	--
					Two thirds	43.3	10.9	304.2	--	--
					Full	65.0	13.8	441.6	--	--
170	Western hemlock	13.0	--	--	Full	47.0	9.4	170.9	--	--
171	Western hemlock	12.9	--	--	Full	74.0	11.0	250.5	--	--
172	Western hemlock	12.1	--	--	Full	54.0	9.3	164.6	--	--
173	Western hemlock	20.0	--	--	Full	65.0	14.3	338.0	---	--
174	Western hemlock	13.9	--	--	Full	67.0	11.8	232.0	--	--
175	Western hemlock	21.8	--	--	Full	67.0	16.3	465.5	--	--
176	Western hemlock	16.2	--	--	Full	69.0	13.3	371.2	--	--
177	Western hemlock	26.7	--	--	Full	85.0	22.3	530.0	--	--
178	Western hemlock	25.9	--	--	Full	59.0	20.0	481.0	--	--
179	Western hemlock	24.9	--	--	Full	66.0	19.6	450.3	--	--
180	Incense cedar	13.0	51.0	56	20	10.3	2.8	13.2	4.2	9.0
					40	20.6	5.4	62.6	[c]27.8	34.9
					60	30.8	8.5	137.2	[c]71.8	65.5
					80	41.0	10.0	235.0	[c]133.3	101.8
181	Incense cedar	27.2	71.2	53	20	14.2	3.5	33.3	12.5	20.8
					40	28.5	7.8	110.8	56.0	54.8
					60	42.8	11.2	292.0	[c]174.0	117.6
					80	57.0	15.5	479.0	[c]310.0	169.0

[b]Percents refer to total height of tree; one third, half, etc., refer to total length of crown.
[c]Branch and foliage weights from samples.

Table A-1 (continued)

Tree No.	Species	d_{bh}	H_o	Age	Crown[b]	H_c	d_c	W_{dc}	W_{db}	W_{df}
		-inches-	-feet-	-years-	-percent-	-feet-	-inches-	-------pounds------		
182	Incense cedar	--	--	--	Half	8.7	2.2	9.5	3.5	6.0
					Full	14.1	3.6	24.1	9.9	14.2
183	Incense cedar	--	--	--	Half	9.8	3.6	20.8	7.7	13.1
					Full	16.3	6.2	61.3	25.4	35.9
184	Incense cedar	--	--	--	Full	1.8	0.8	0.3	0.1	0.2
185	Incense cedar	--	--	--	Full	2.4	0.9	0.5	--	--
186	Western redcedar	11.8	--	--	One third	18.3	3.9	25.8	--	--
					Two thirds	36.6	6.9	100.7	--	--
					Full	55.0	9.1	179.4	--	--
187	Western redcedar	18.8	--	--	One third	19.3	4.9	64.8	--	--
					Two thirds	38.6	8.5	147.4	--	--
					Full	58.0	11.0	265.9	--	--
188	Western redcedar	3.1	--	--	One third	5.2	1.1	1.8	--	--
					Two thirds	10.4	2.0	5.9	--	--
189	Western redcedar	6.3	--	--	One third	7.1	2.3	7.5	--	--
					Two thirds	14.2	3.9	31.1	--	--
					Full	21.3	5.1	55.5	--	--
190	Western redcedar	13.1	--	--	Full	63.0	9.2	246.0	--	--
191	Western redcedar	17.1	--	--	Full	60.0	12.0	217.3	--	--
192	Western redcedar	12.0	--	--	Full	56.0	8.8	187.6	--	--
193	Western redcedar	9.8	--	--	Full	44.0	7.2	103.6	--	--
194	Western redcedar	12.4	--	--	Full	51.0	8.7	159.0	--	--
195	Western redcedar	13.3	--	--	Full	52.0	10.6	182.6	--	--
196	Western redcedar	11.6	--	--	Full	55.0	8.4	124.6	--	--
197	Western redcedar	14.4	--	--	Full	65.0	10.1	147.8	--	--

[b]Percents refer to total height of tree; one third, half, etc., refer to total length of crown.

Table A-1 (continued)

Tree No.	Species	d_{bh}	H_o	Age	Crown[b]	H_c	d_c	W_{dc}	W_{db}	W_{df}
		-inches-	-feet-	-years-	-percent-	-feet-	-inches-		-pounds-	
198	Western redcedar	14.6	--	--	Full	65.0	9.0	237.6	--	--
199	Western redcedar	15.7	--	--	Full	60.0	11.0	238.3	--	--
200	Western redcedar	16.0	--	--	Full	69.0	10.6	195.0	--	--
201	Western larch	20.1	--	--	One third	27.3	6.1	57.5	--	--
					Two thirds	54.6	11.5	205.7	--	--
					Full	82.0	14.8	255.2	--	--
202	Western larch	14.0	--	--	One third	16.6	6.0	52.0	--	--
					Two thirds	33.3	8.9	108.5	--	--
					Full	50.0	9.9	162.7	--	--
203	Western larch	10.0	--	--	One third	15.0	4.5	12.5	--	--
					Two thirds	30.0	6.9	25.3	--	--
					Full	45.0	8.0	32.7	--	--
204	Western larch	12.5	--	--	One third	13.3	3.6	18.0	--	--
					Two thirds	26.6	6.5	41.0	--	--
					Full	40.0	7.8	68.4	--	--
205	Western larch	7.7	46.8	34	One third	10.0	2.2	6.7	3.0	3.7
					Two thirds	20.0	3.1	25.9	13.5	12.4
					Full	30.0	5.8	46.9	27.5	19.4
206	Western larch	2.2	14.0	22	Half	4.6	1.0	1.6	0.7	0.9
					Full	9.2	1.8	4.2	2.2	2.0
207	Western larch	25.8	135.6	200	One third	23.8	6.3	60.2	34.2	26.0
					Two thirds	47.5	9.4	185.2	126.6	58.6
					Full	71.2	14.8	372.2	272.5	99.7
208	Western larch	12.3	86.0	86	One third	12.7	2.6	23.1	15.2	7.9
					Two thirds	25.3	4.4	46.3	30.4	15.9
					Full	38.0	5.4	66.3	42.4	23.9

[b]Percents refer to total height of tree; one third, half, etc., refer to total length of crown.

Table A-1 (continued)

Tree No.	Species	d_{bh}	H_o	Age	Crown[b]	H_c	d_c	W_{dc}	W_{db}	W_{df}
		-inches-	-feet-	-years-	-percent-	-feet-	-inches-	-------	pounds	-------
209	Western larch	26.2	127.9	216	One third	25.4	5.5	63.5	52.2	11.3
					Two thirds	50.8	9.6	171.4	130.8	40.6
					Full	76.3	14.4	338.8	264.7	74.1
210	Western larch	5.7	41.5	30	One third	10.4	1.8	5.7	2.5	3.2
					Two thirds	20.8	2.8	17.8	8.8	9.0
					Full	31.7	3.8	29.9	16.2	13.7
211	Western larch	11.9	88.5	93	One third	15.5	3.0	25.6	17.8	7.8
					Two thirds	31.0	4.7	51.4	36.3	15.1
					Full	46.5	5.7	76.2	52.4	23.8

[b] Percents refer to total height of tree; one third, half, etc., refer to total length of crown.

APPENDIX B

RELATIONS BETWEEN DRY WEIGHT OF CROWN (AS WELL AS COMPONENTS DRY BRANCHWOOD AND DRY FOLIAGE), CROWN LENGTH, AND STEM DIAMETER

Figures B-1 to B-17, crown; figures B-18 to B-25, branchwood; and figures B-26 to B-35, foliage.

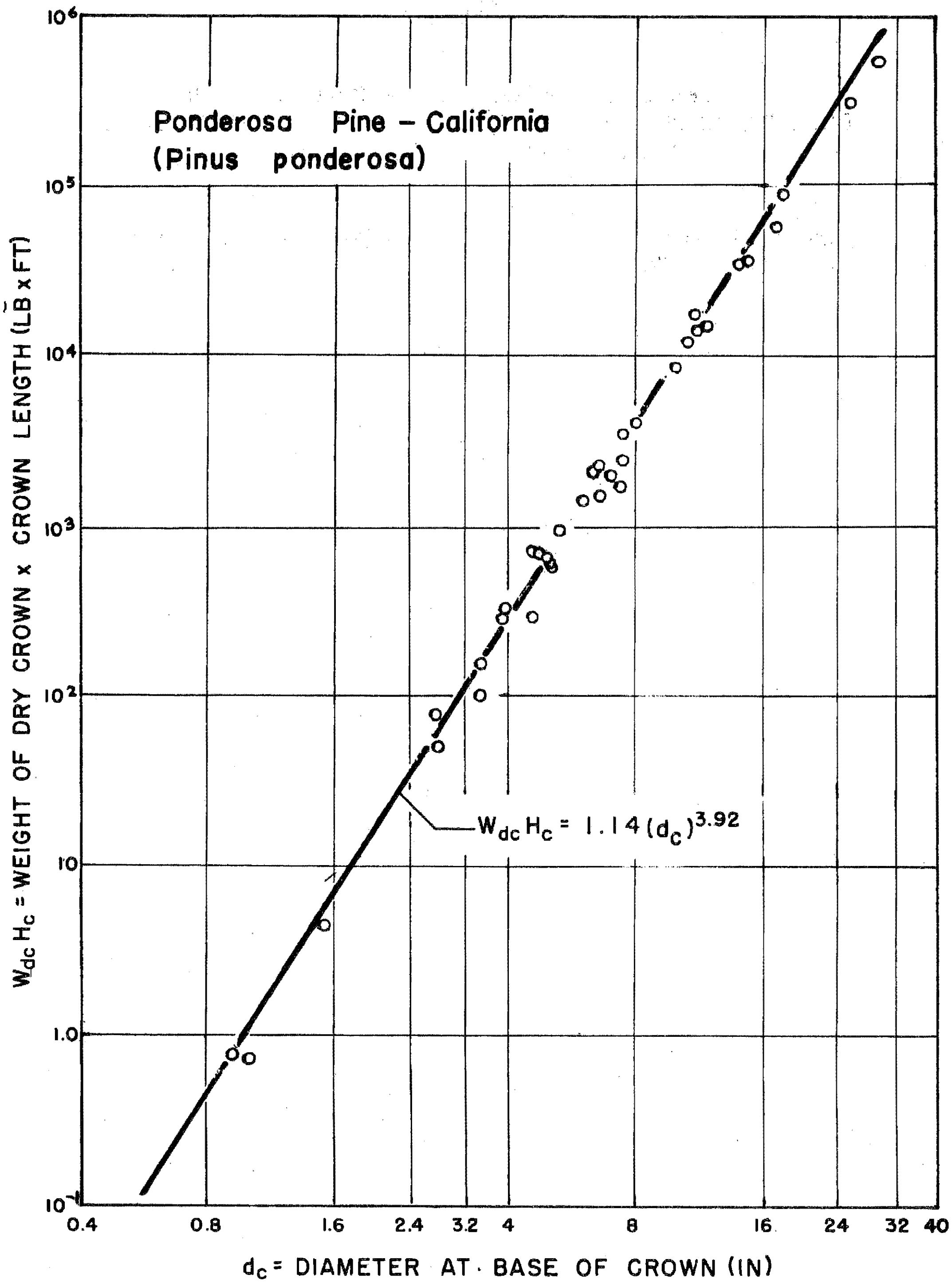

Figure B-1.--Relations between dry crown weight, length, and base of crown stem diameter inside bark--ponderosa pine (California)

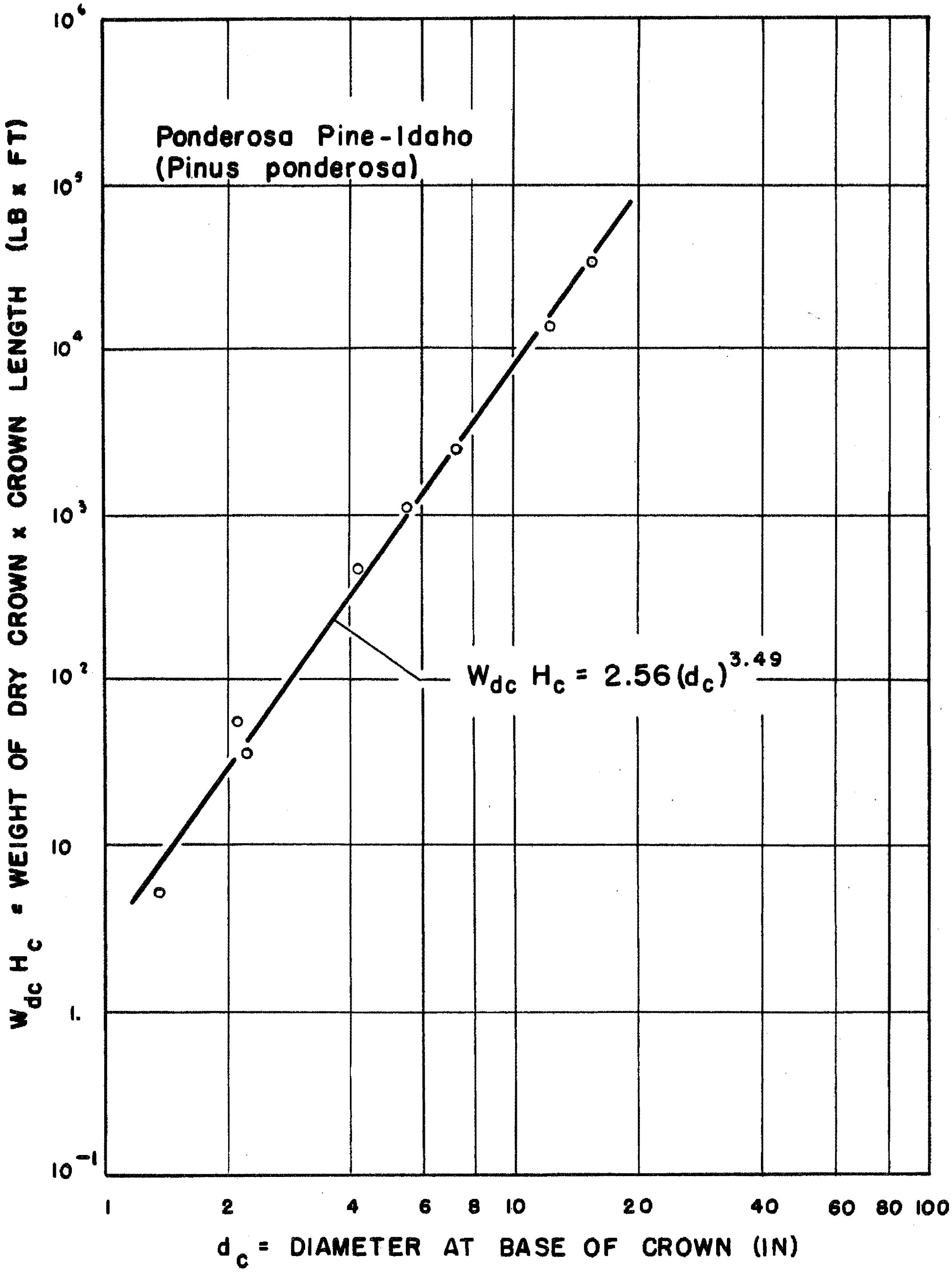

Figure B-2.--Relations between dry crown weight, length, and base of crown stem diameter inside bark--ponderosa pine (Idaho)

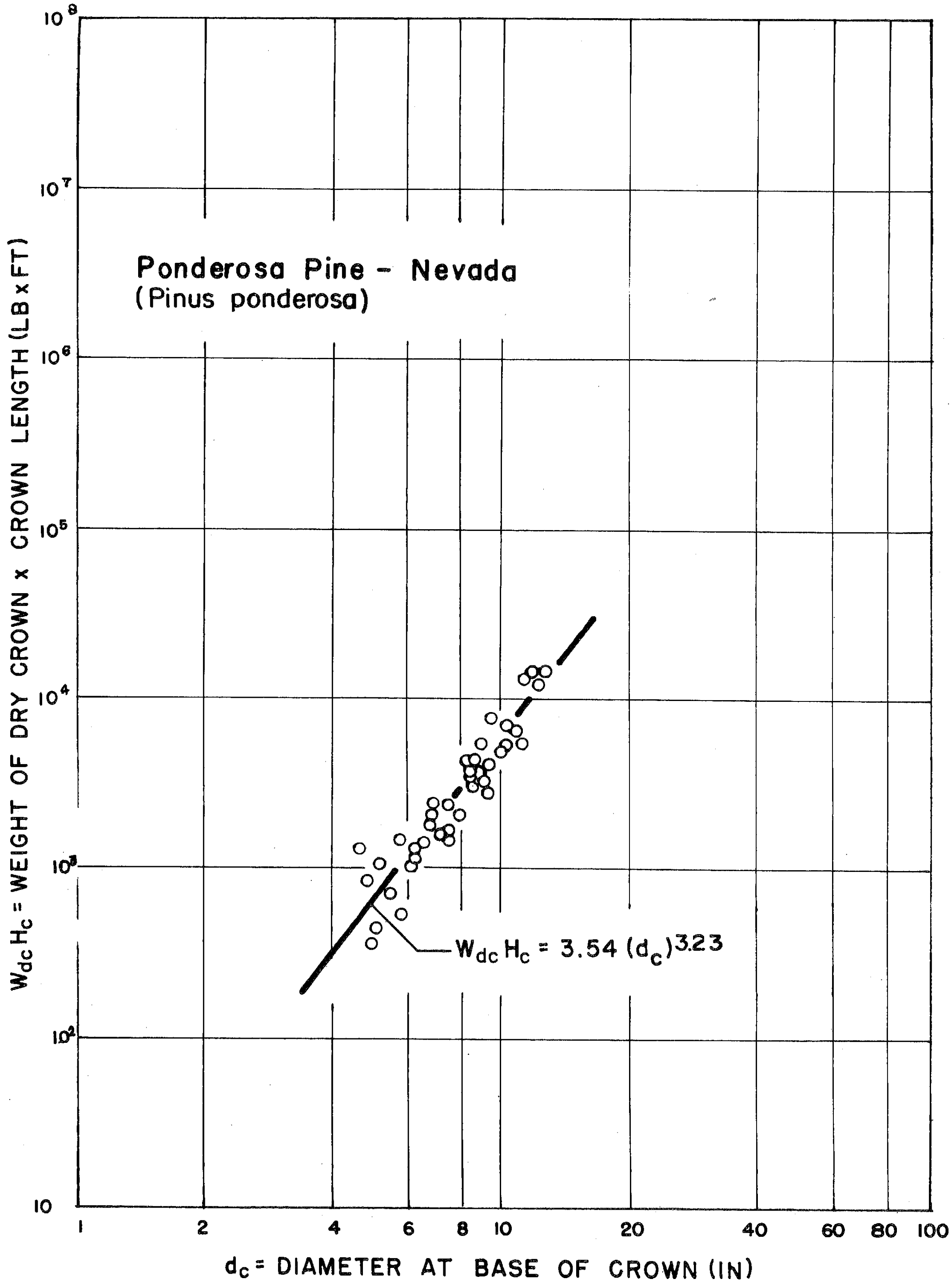

Figure B-3.--Relations between dry crown weight, length, and base of crown stem diameter inside bark--ponderosa pine (Nevada)

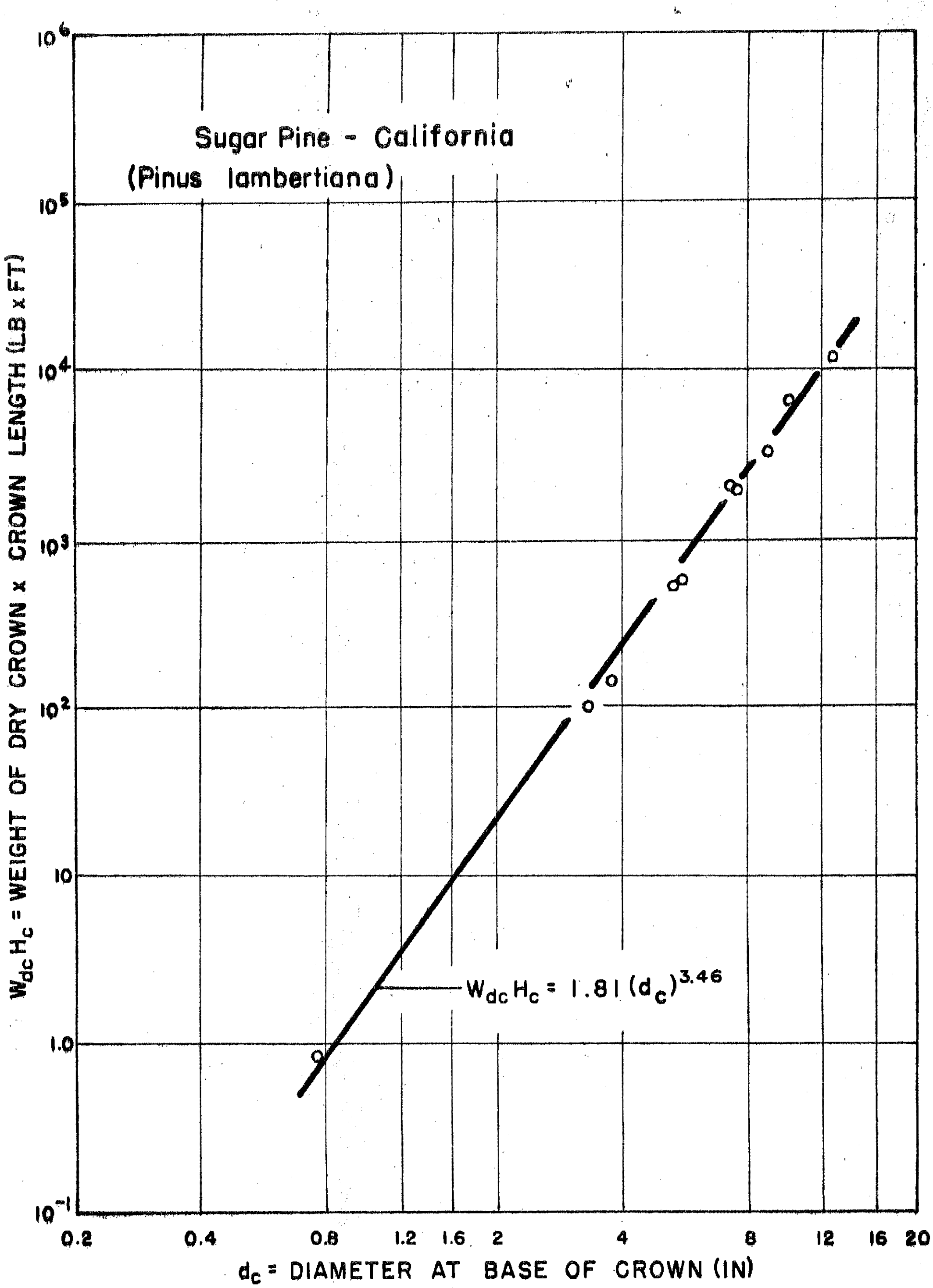

Figure B-4.--Relations between dry crown weight, length, and base of crown stem diameter inside bark--sugar pine (California)

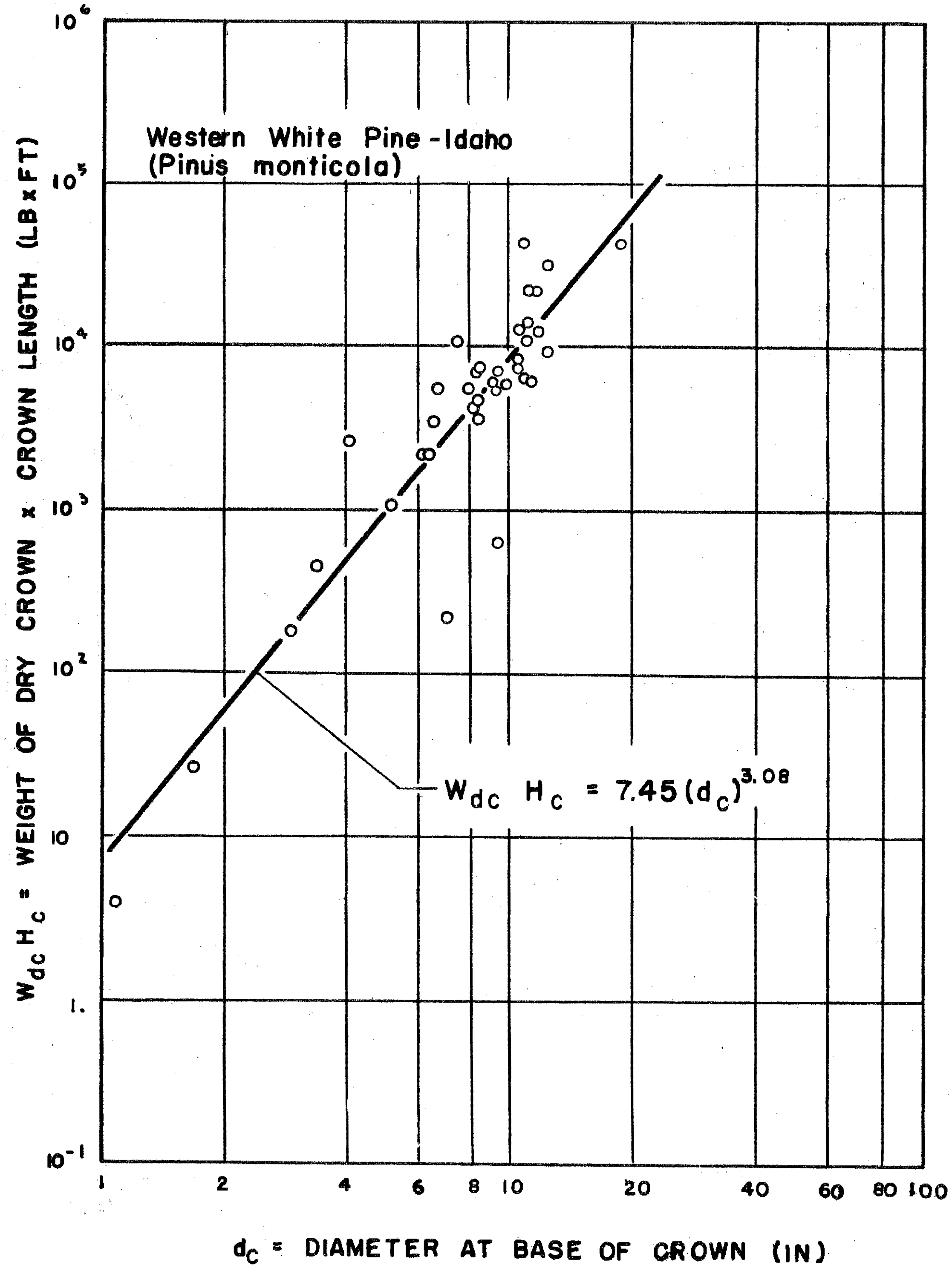

Figure B-5.--Relations between dry crown weight, length, and base of crown stem diameter inside bark--western white pine (Idaho)

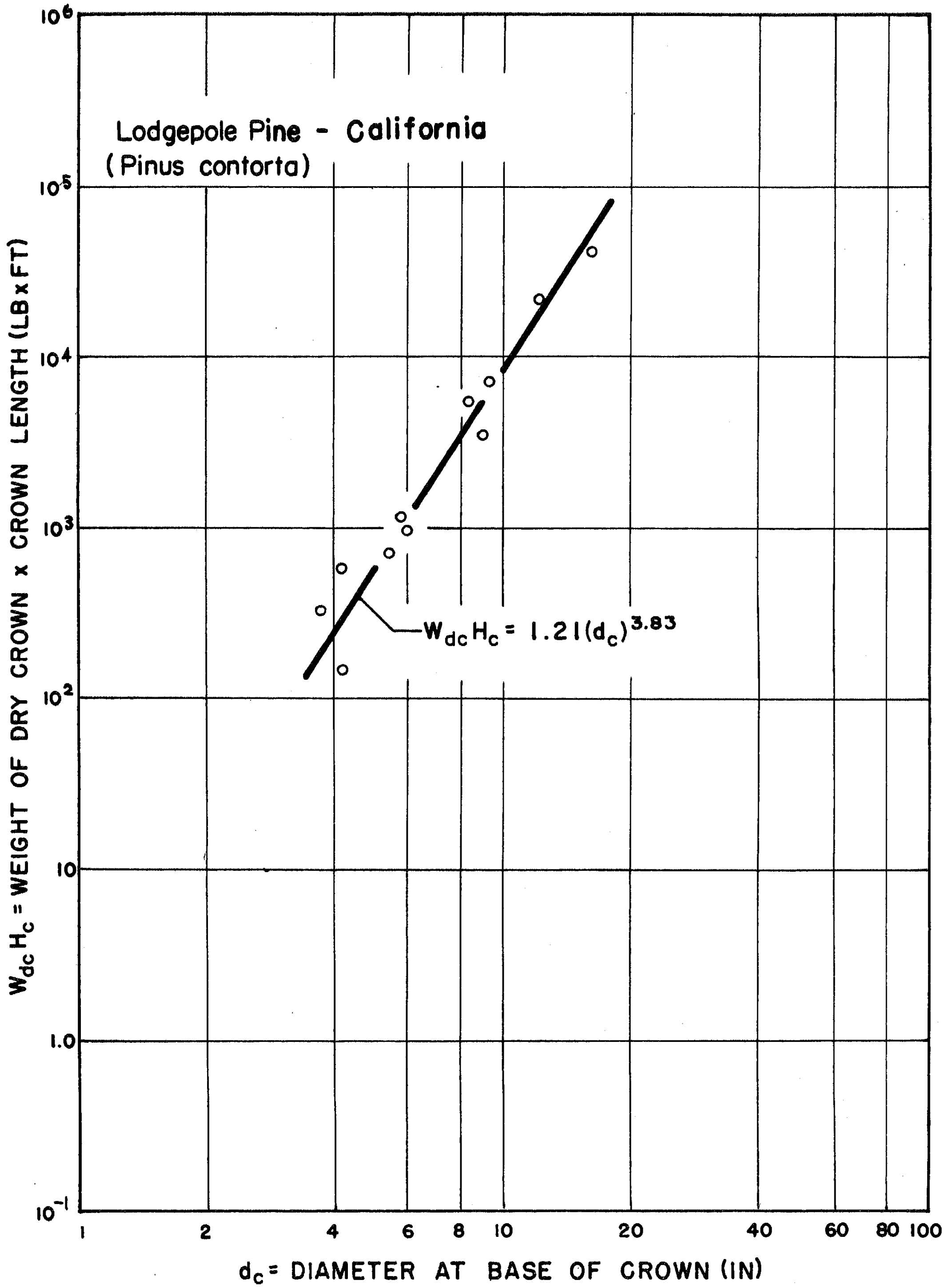

Figure B-6.--Relations between dry crown weight, length, and base of crown stem diameter inside bark--lodgepole pine (California)

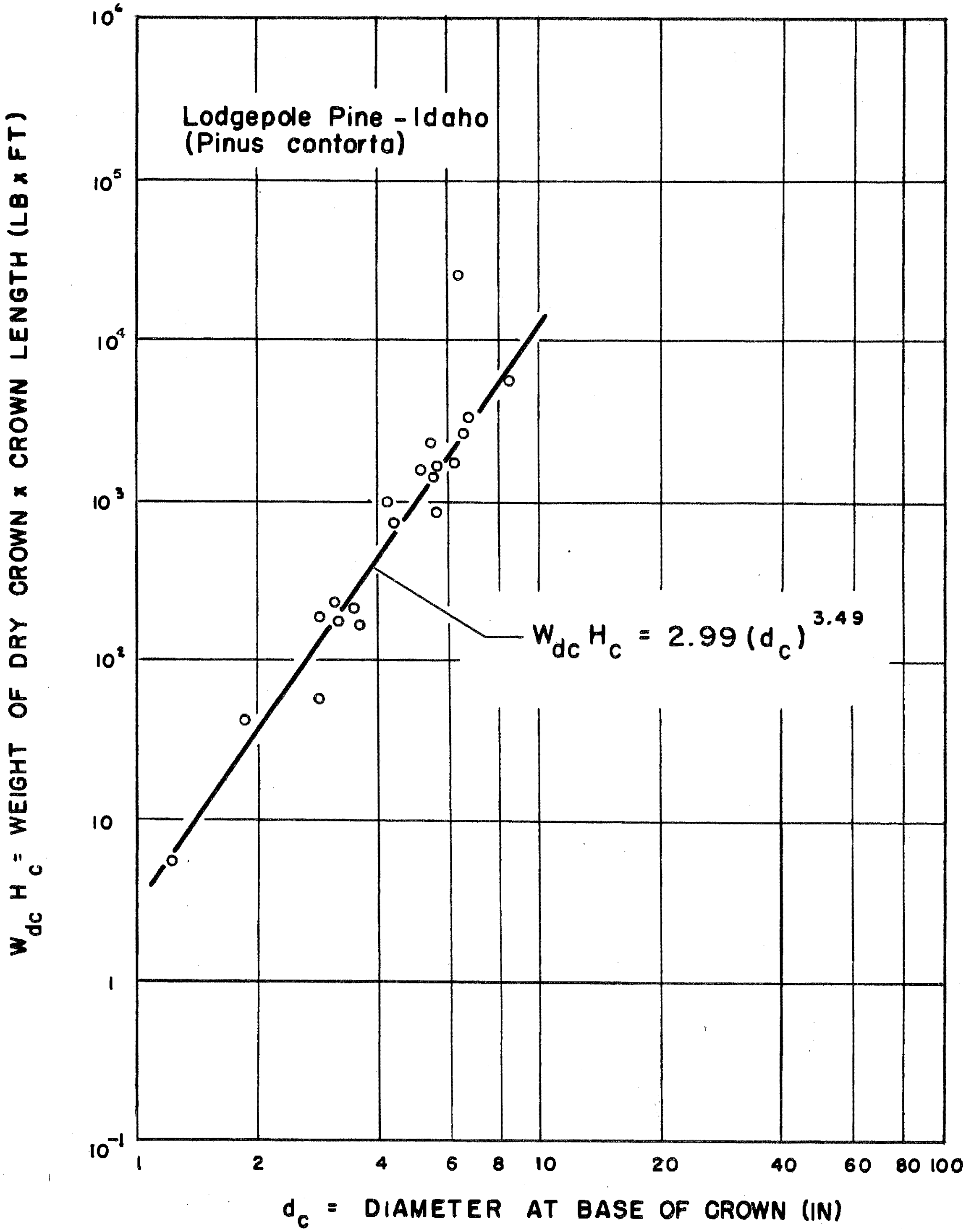

Figure B-7.--Relations between dry crown weight, length, and base of crown stem diameter inside bark--lodgepole pine (Idaho)

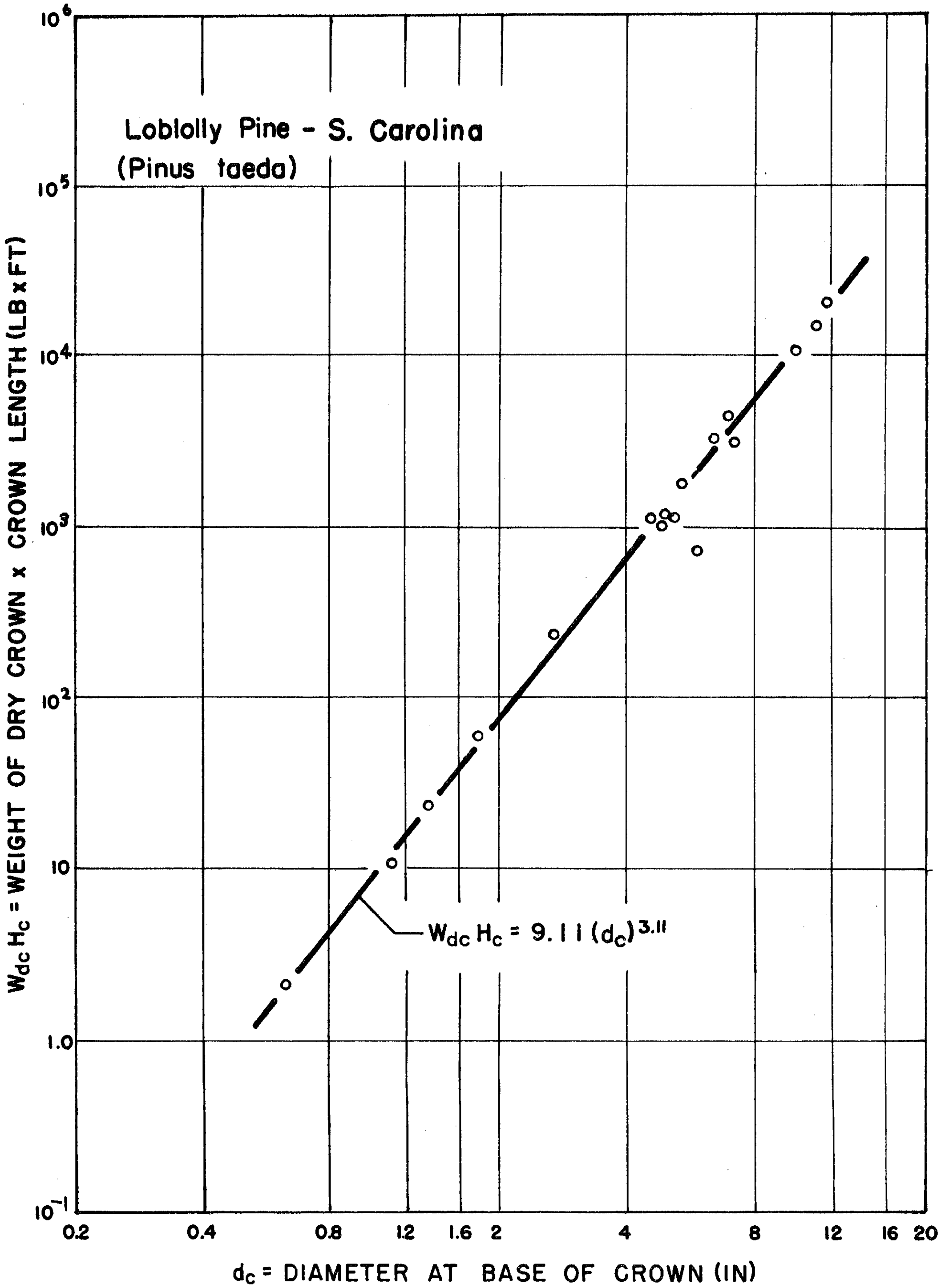

Figure B-8.--Relations between dry crown weight, length, and base of crown stem diameter inside bark--loblolly pine (S. Carolina)

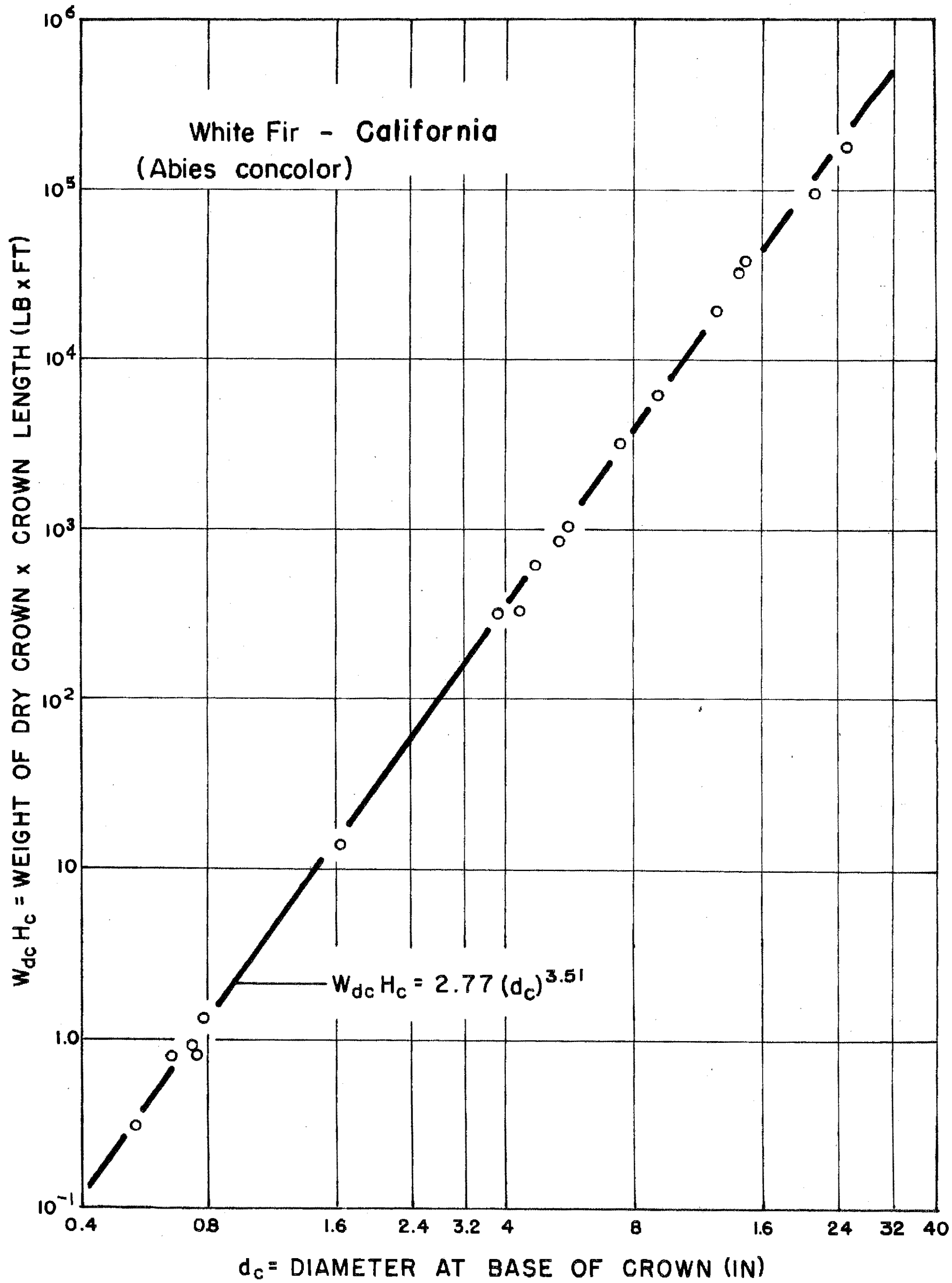

Figure B-9.--Relations between dry crown weight, length, and base of crown stem diameter inside bark--white fir (California)

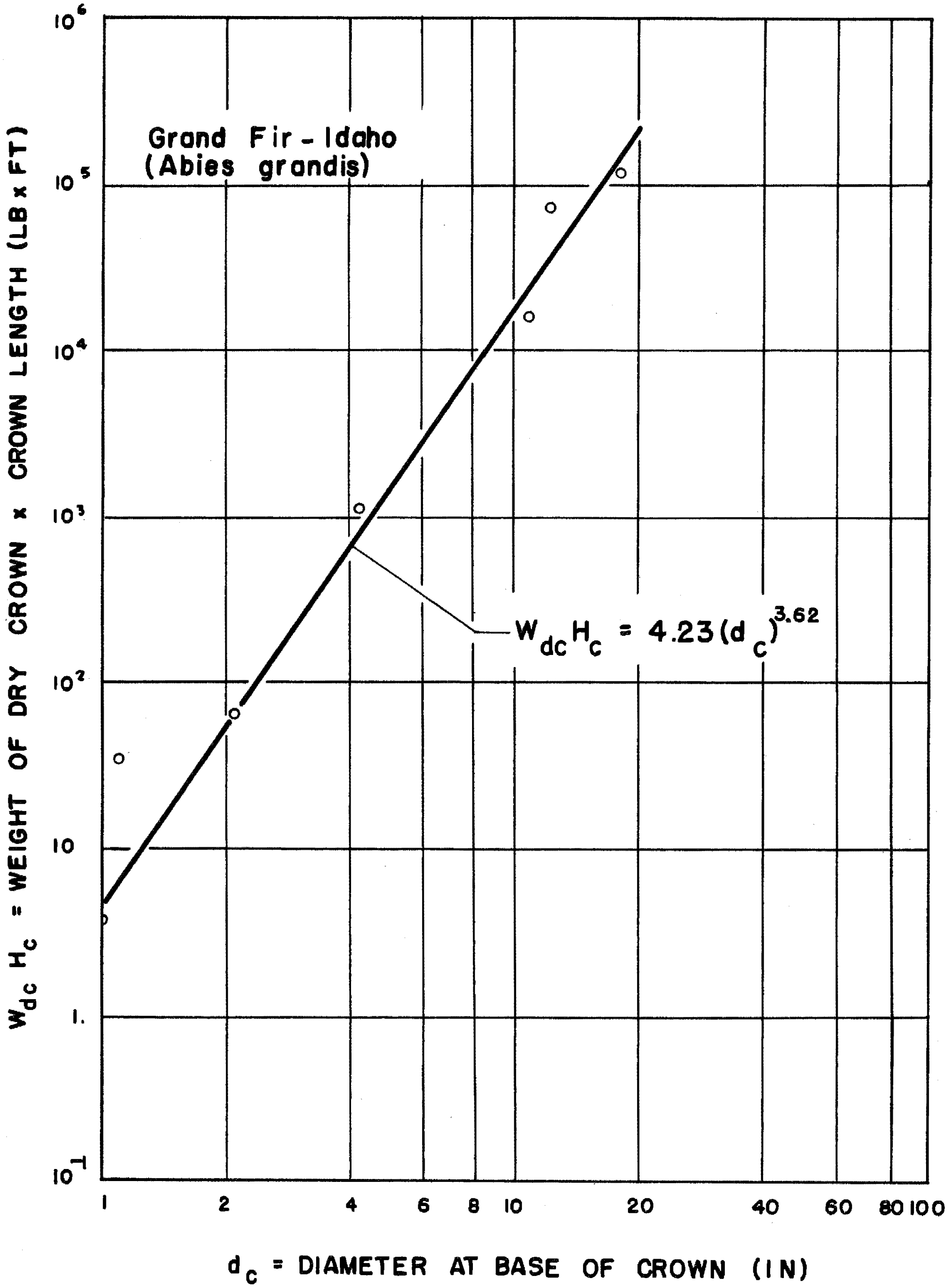

Figure B-10.--Relations between dry crown weight, length, and base of crown stem diameter inside bark--grand fir (Idaho)

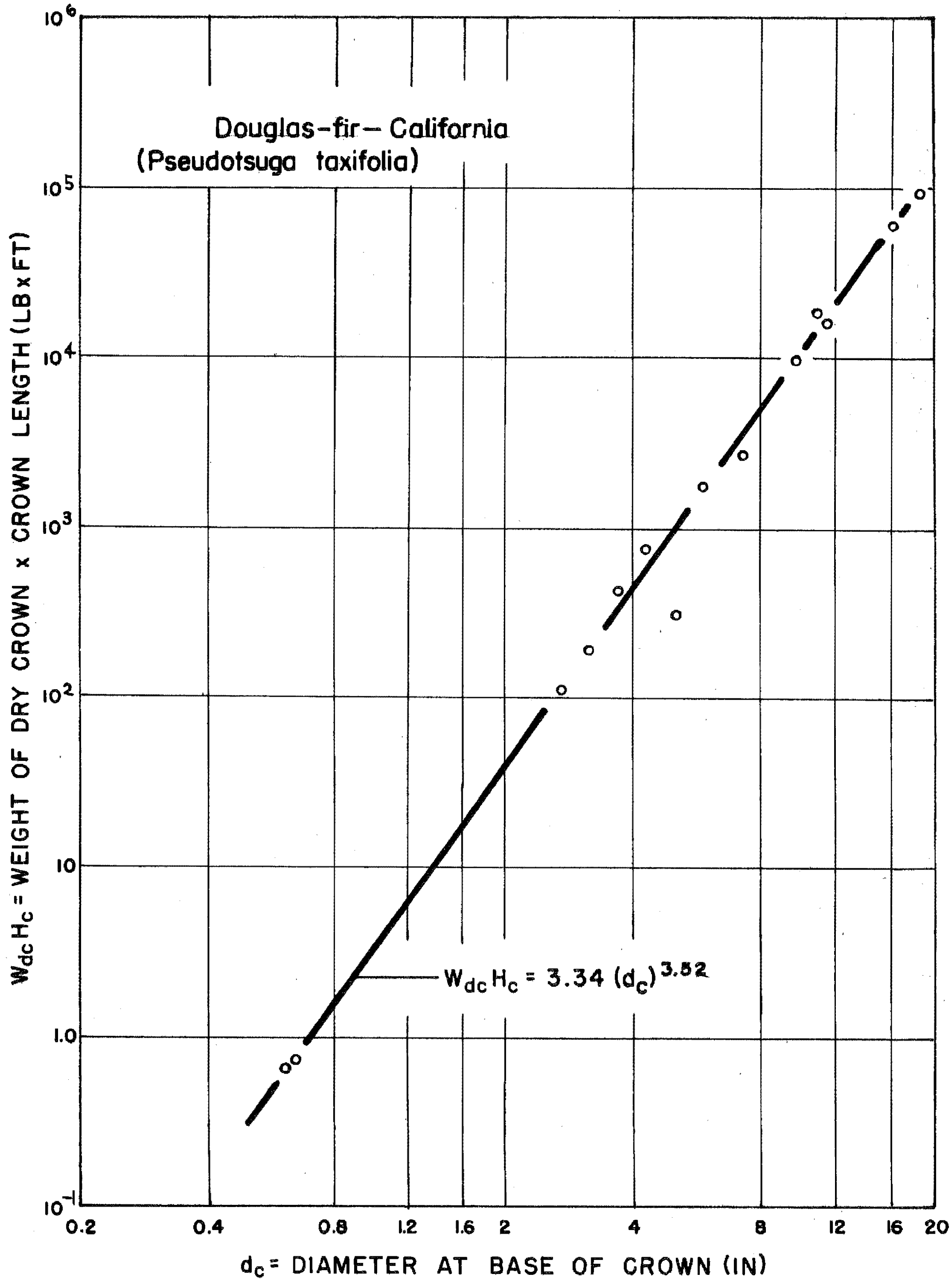

Figure B-11.--Relations between dry crown weight, length, and base of crown stem diameter inside bark--Douglas-fir (California)

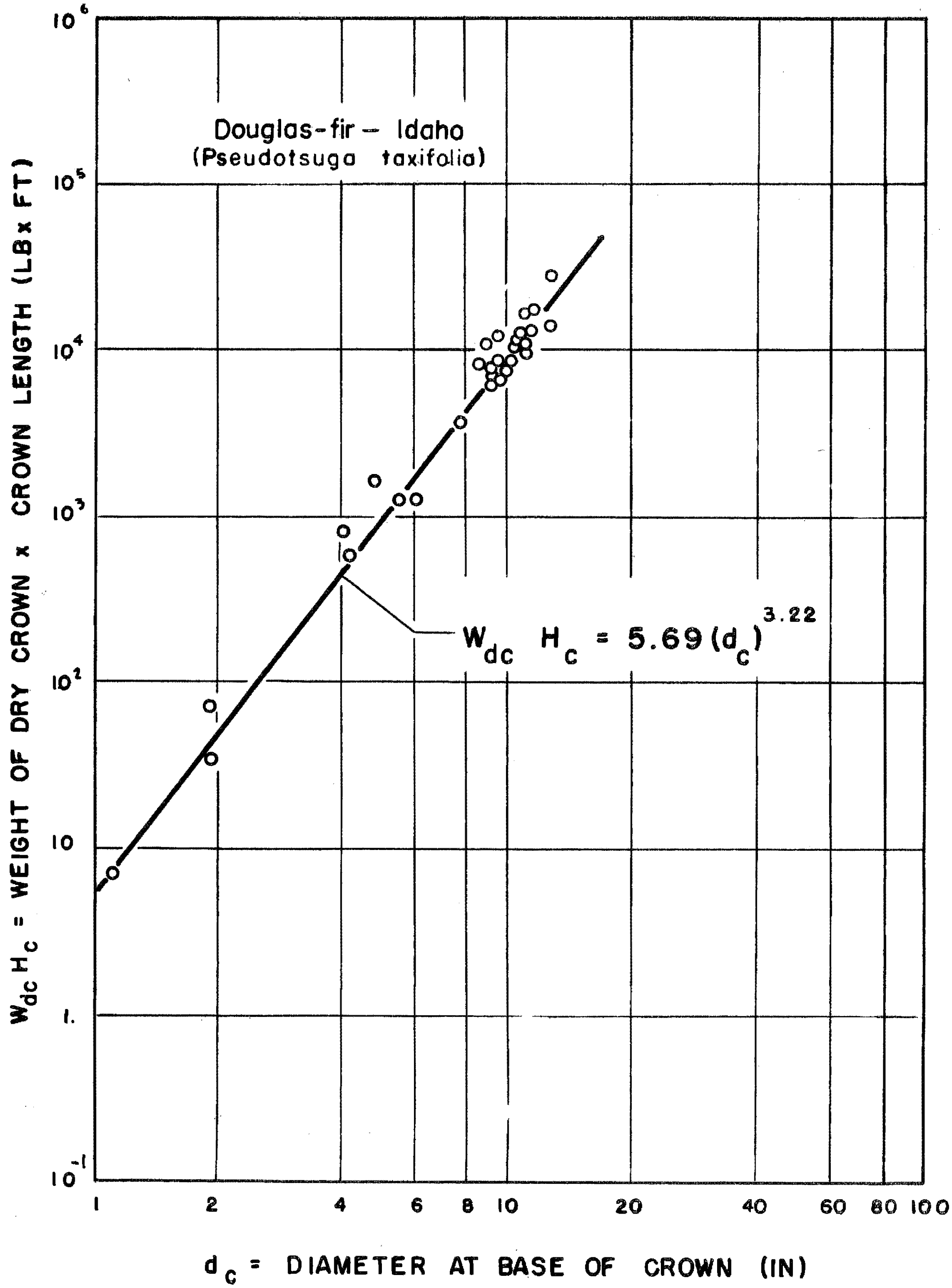

Figure B-12.--Relations between dry crown weight, length, and base of crown stem diameter inside bark--Douglas-fir (Idaho)

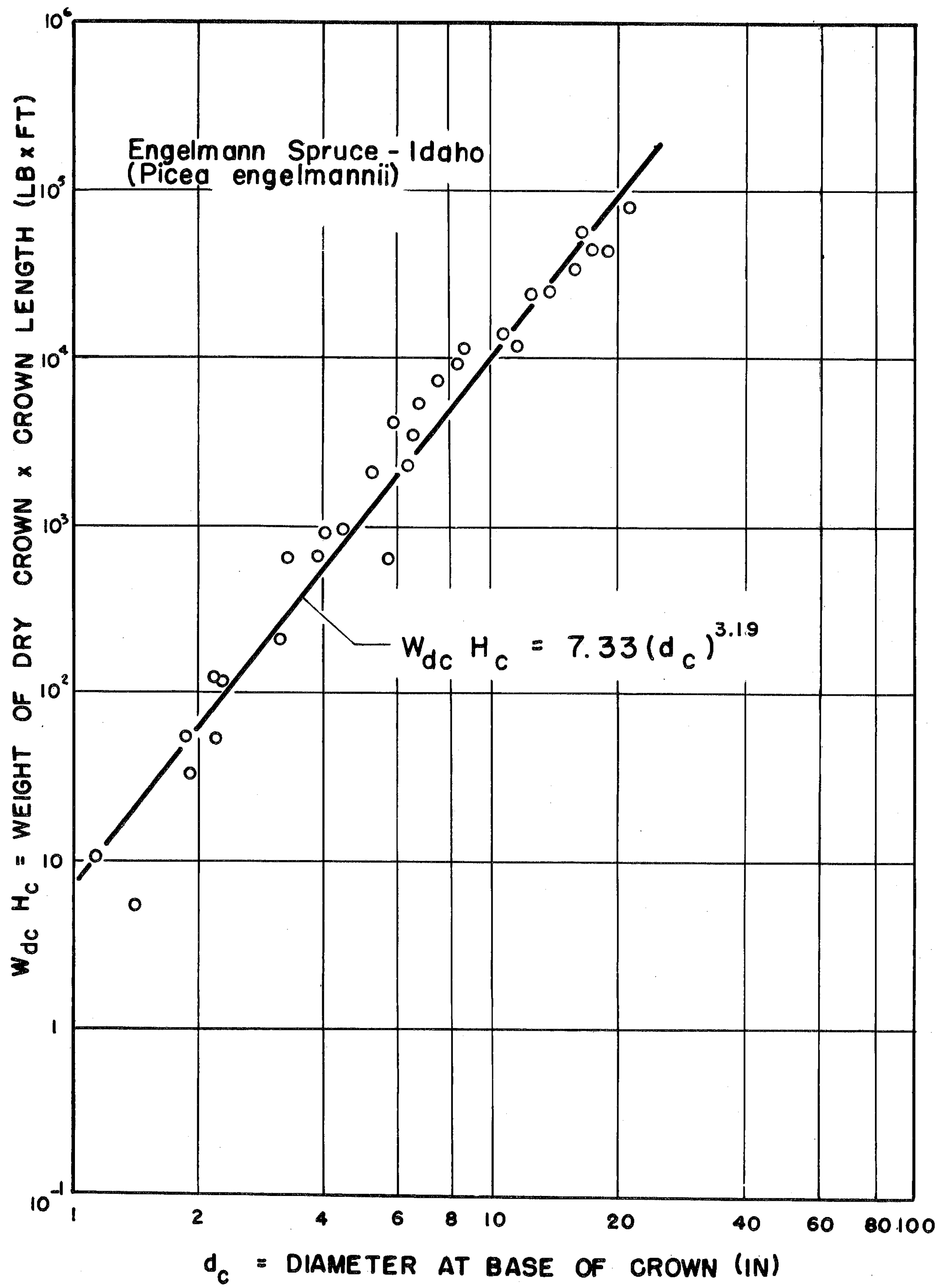

Figure B-13.--Relations between dry crown weight, length, and base of crown stem diameter inside bark--Engelmann spruce (Idaho)

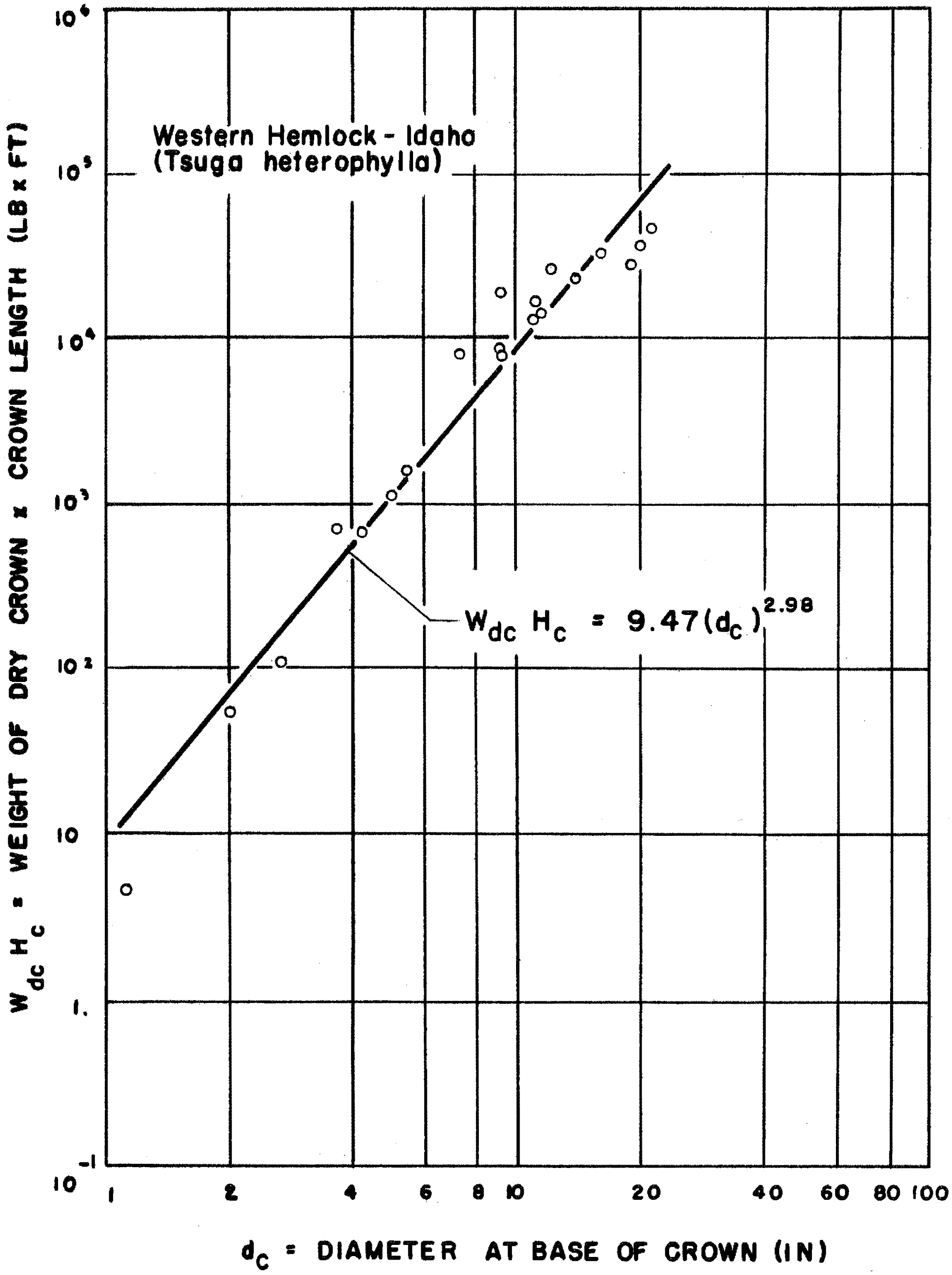

Figure B-14.--Relations between dry crown weight, length, and base of crown stem diameter inside bark--western hemlock (Idaho)

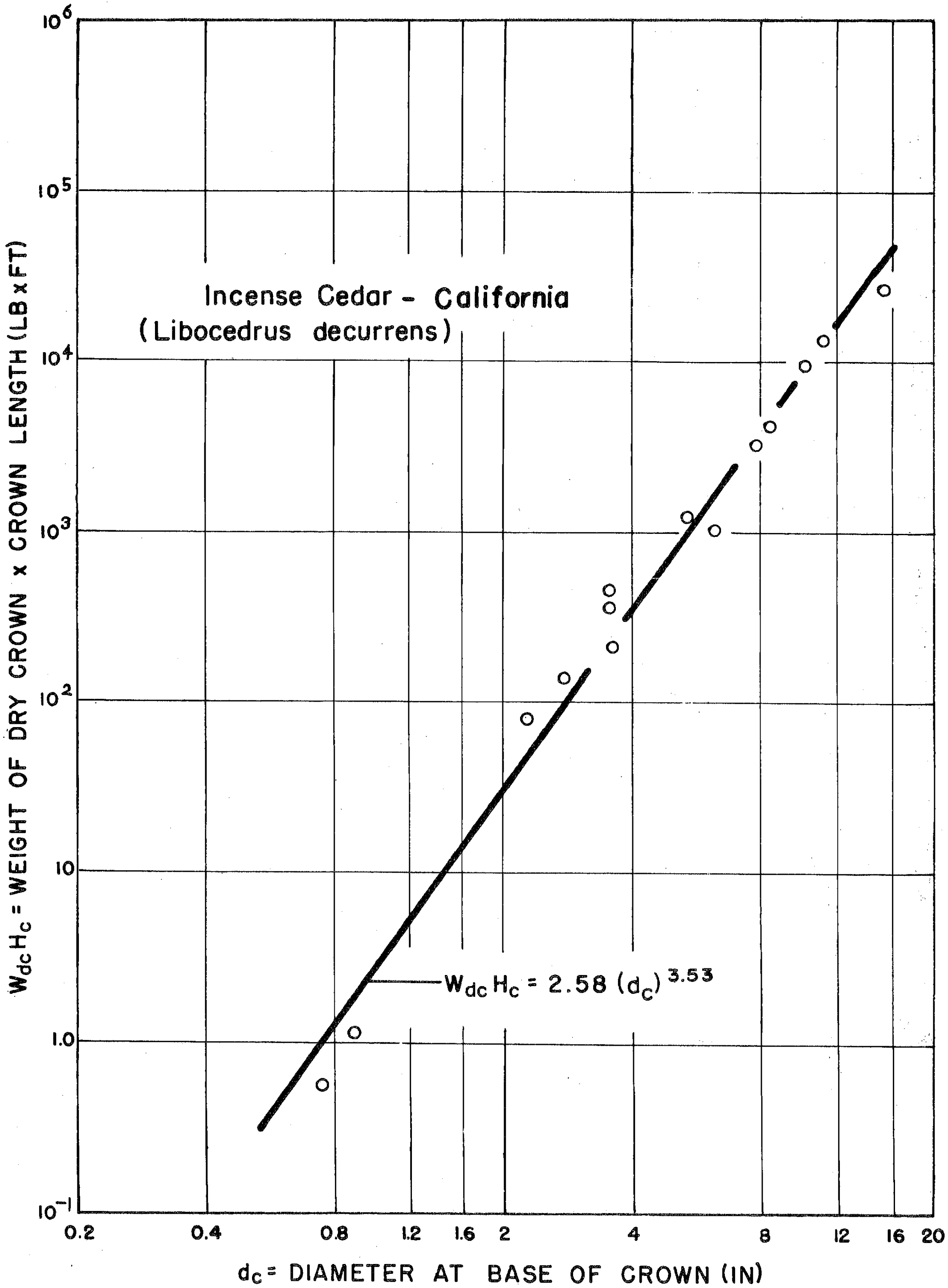

Figure B-15.--Relations between dry crown weight, length, and base of crown stem diameter inside bark--incense cedar (California)

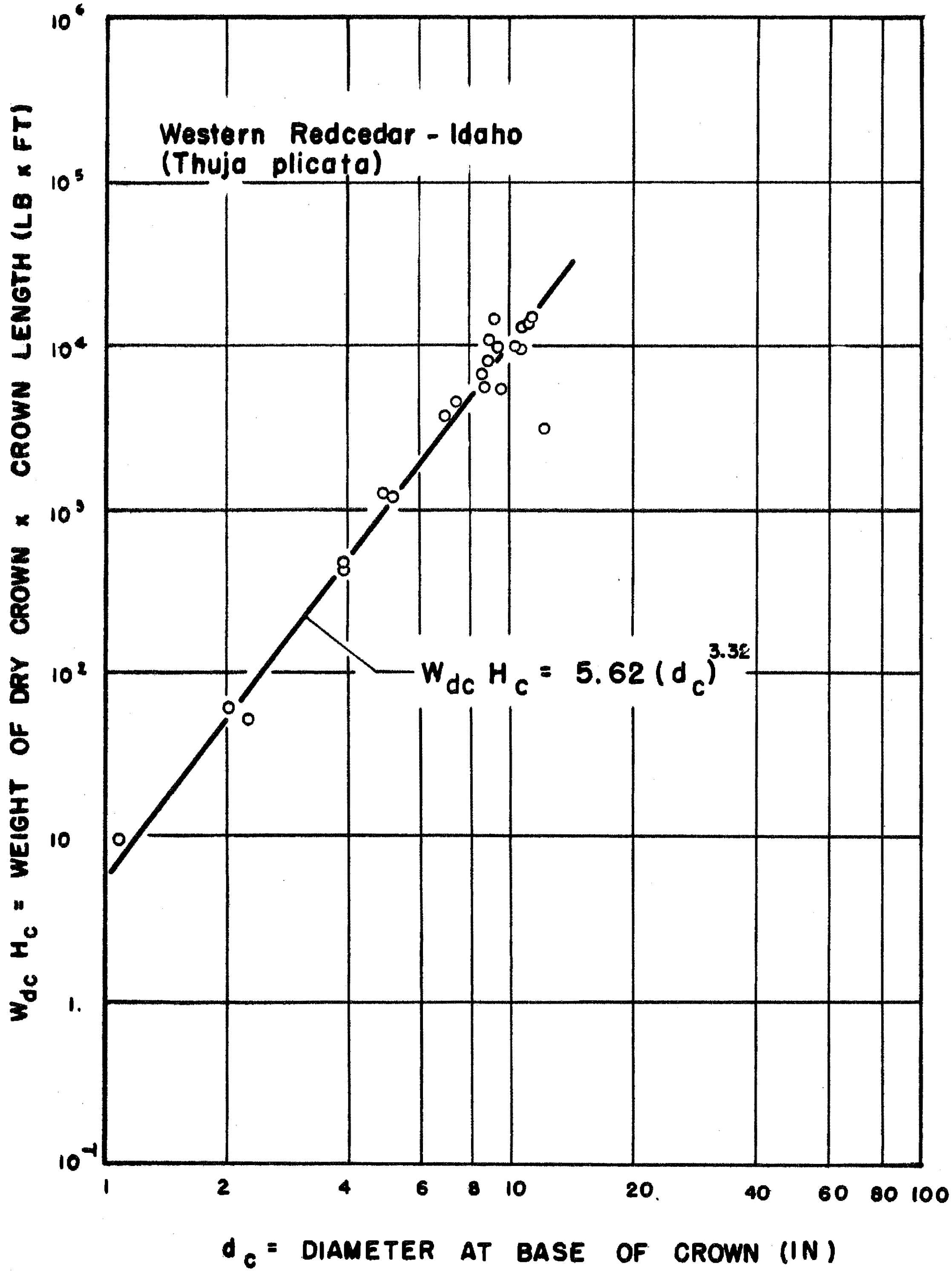

Figure B-16.--Relations between dry crown weight, length, and base of crown stem diameter inside bark--western redcedar (Idaho)

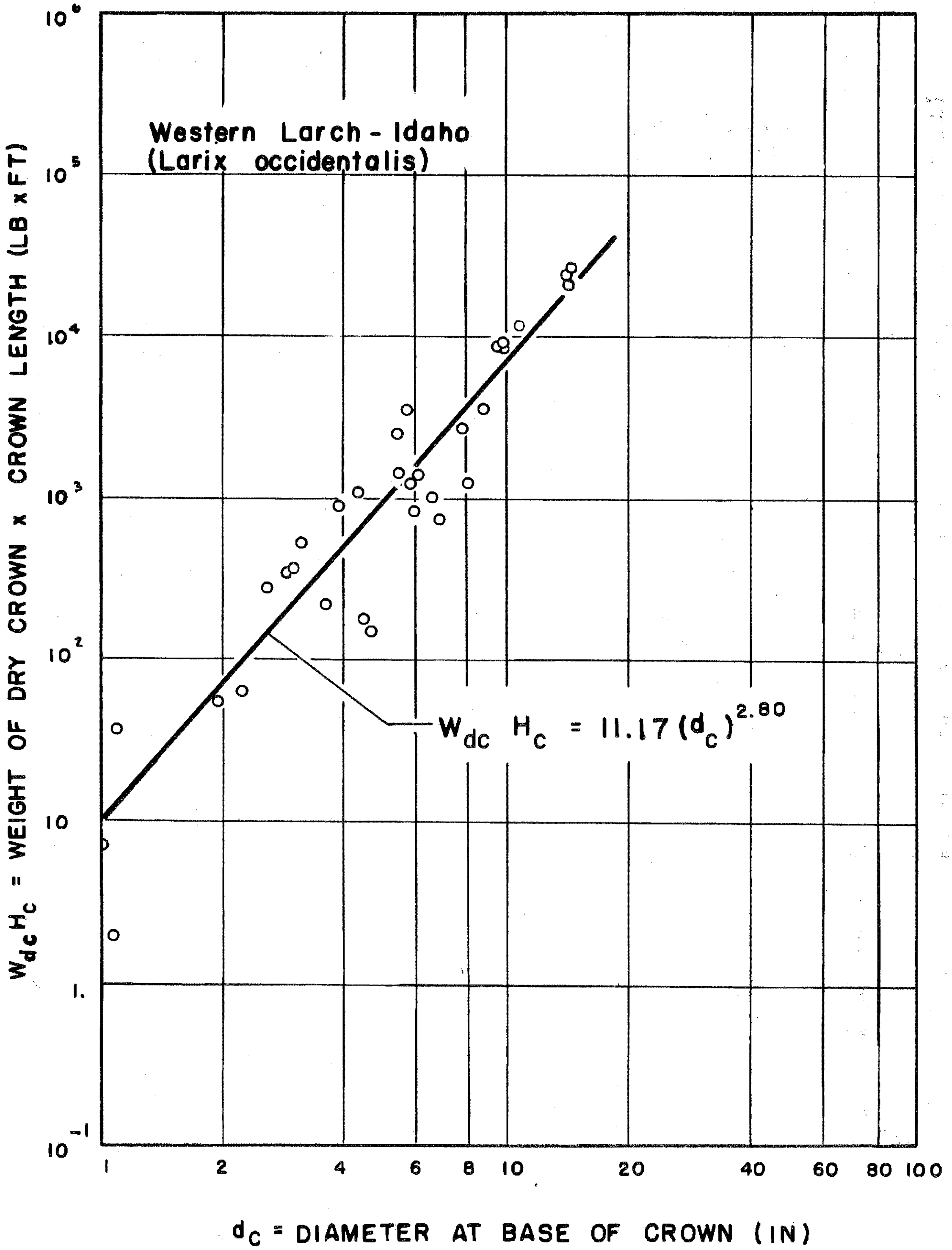

Figure B-17.--Relations between dry crown weight, length, and base of crown stem diameter inside bark--western larch (Idaho)

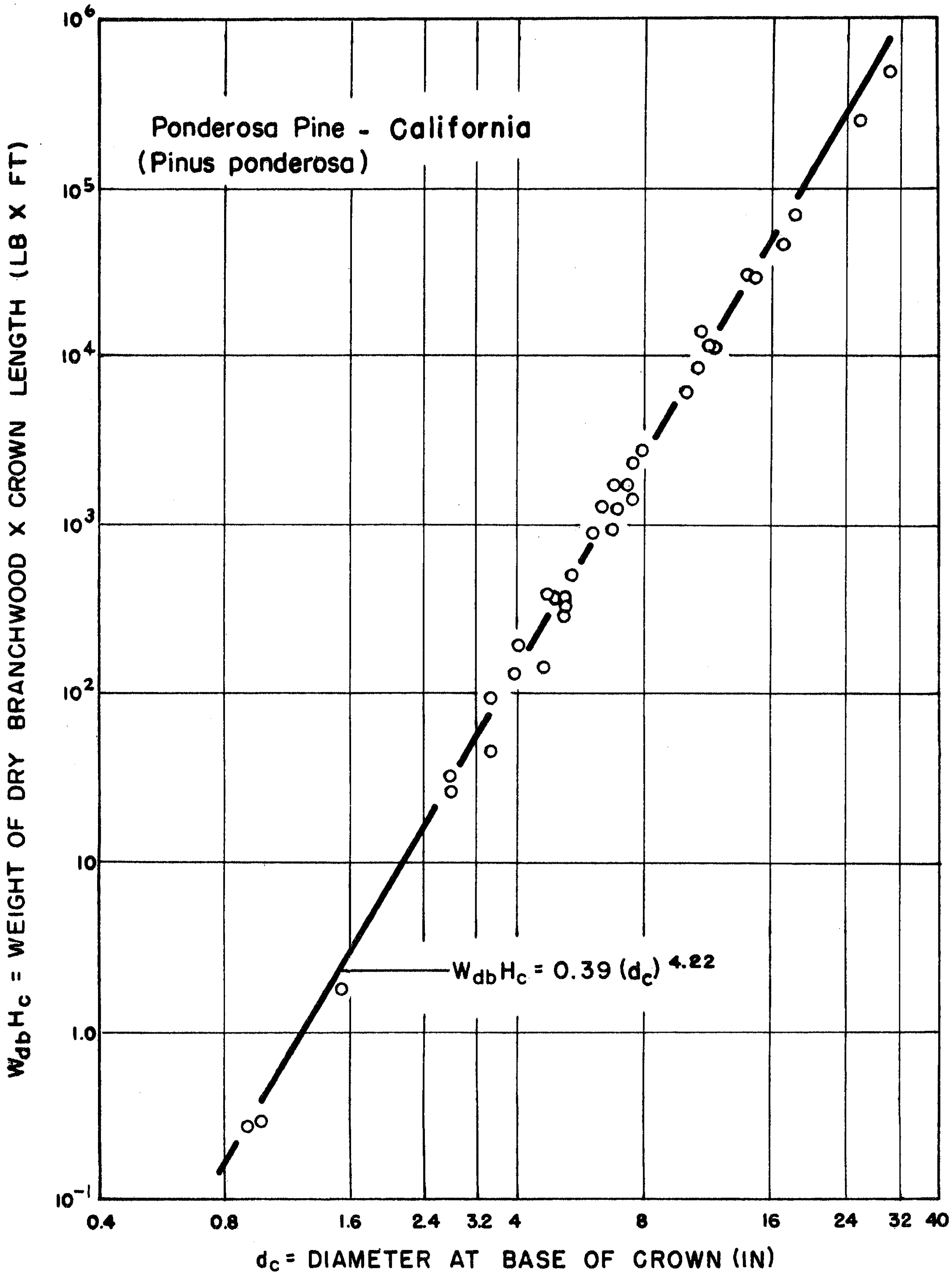

Figure B-18.--Relations between dry branchwood weight, crown length, and base of crown stem diameter inside bark--ponderosa pine (California)

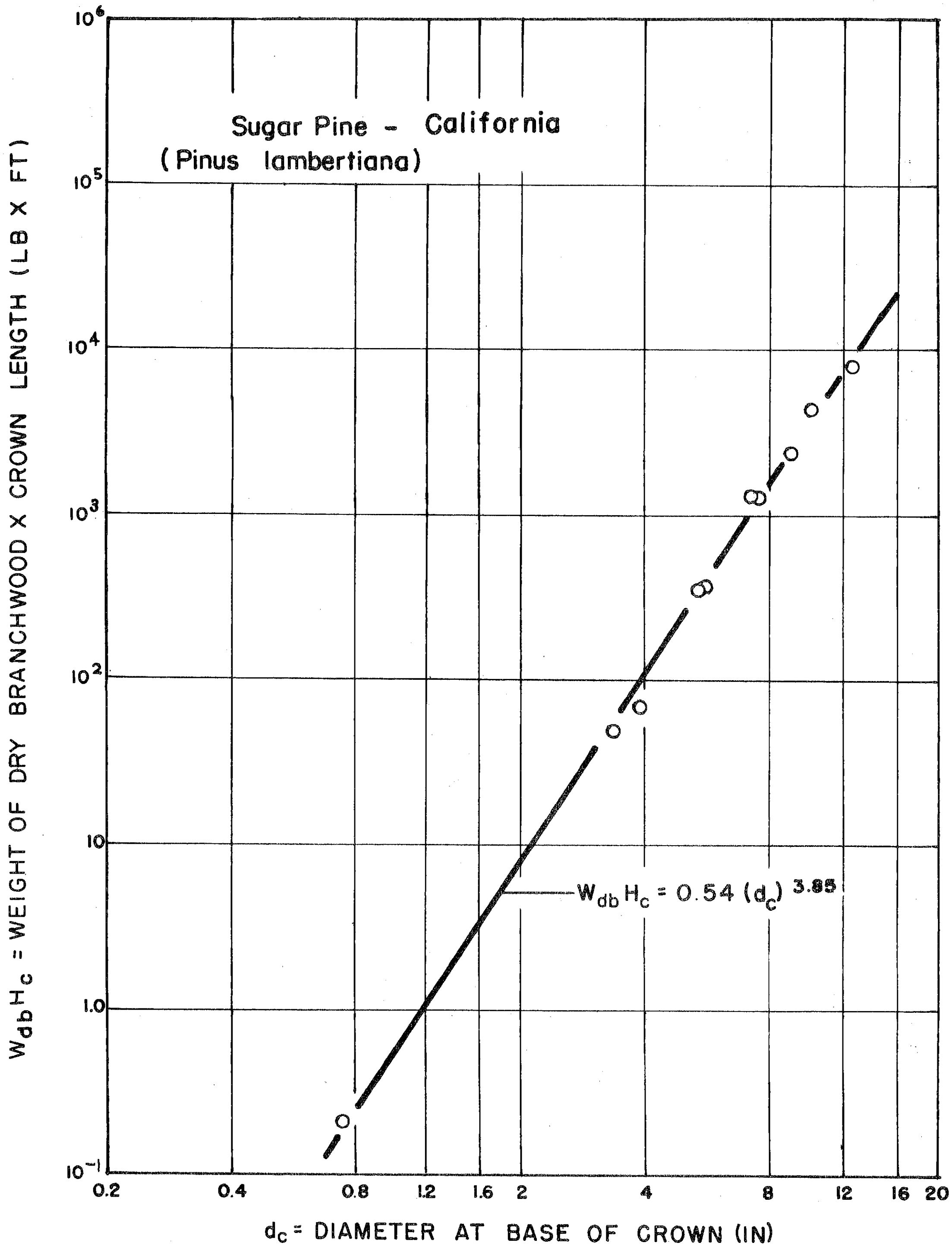

Figure B-19.--Relations between dry branchwood weight, crown length, and base of crown stem diameter inside bark--sugar pine (California)

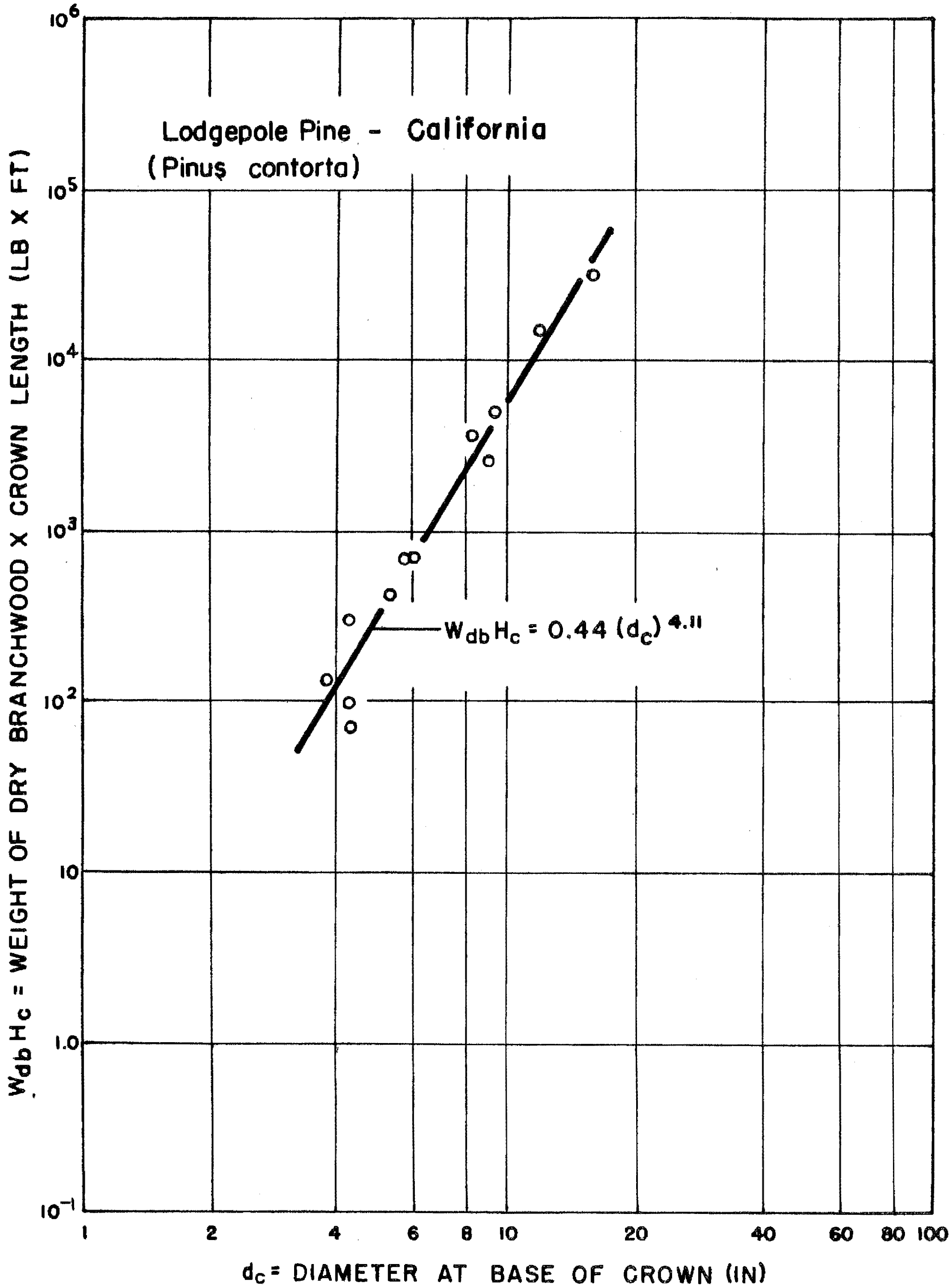

Figure B-20.--Relations between dry branchwood weight, crown length, and base of crown stem diameter inside bark--lodgepole pine (California)

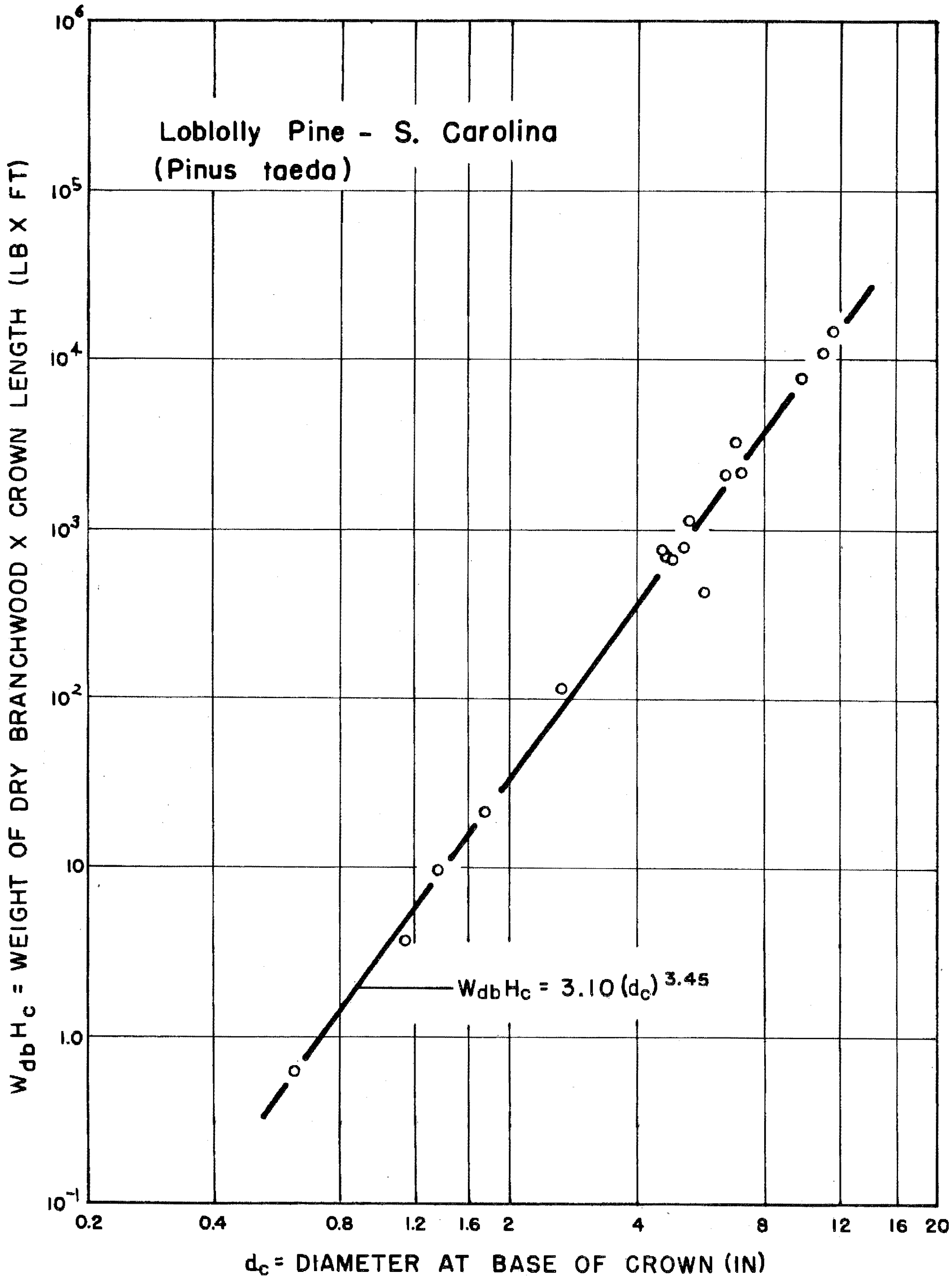

Figure B-21.--Relations between dry branchwood weight, crown length, and base of crown stem diameter inside bark--loblolly pine (S. Carolina)

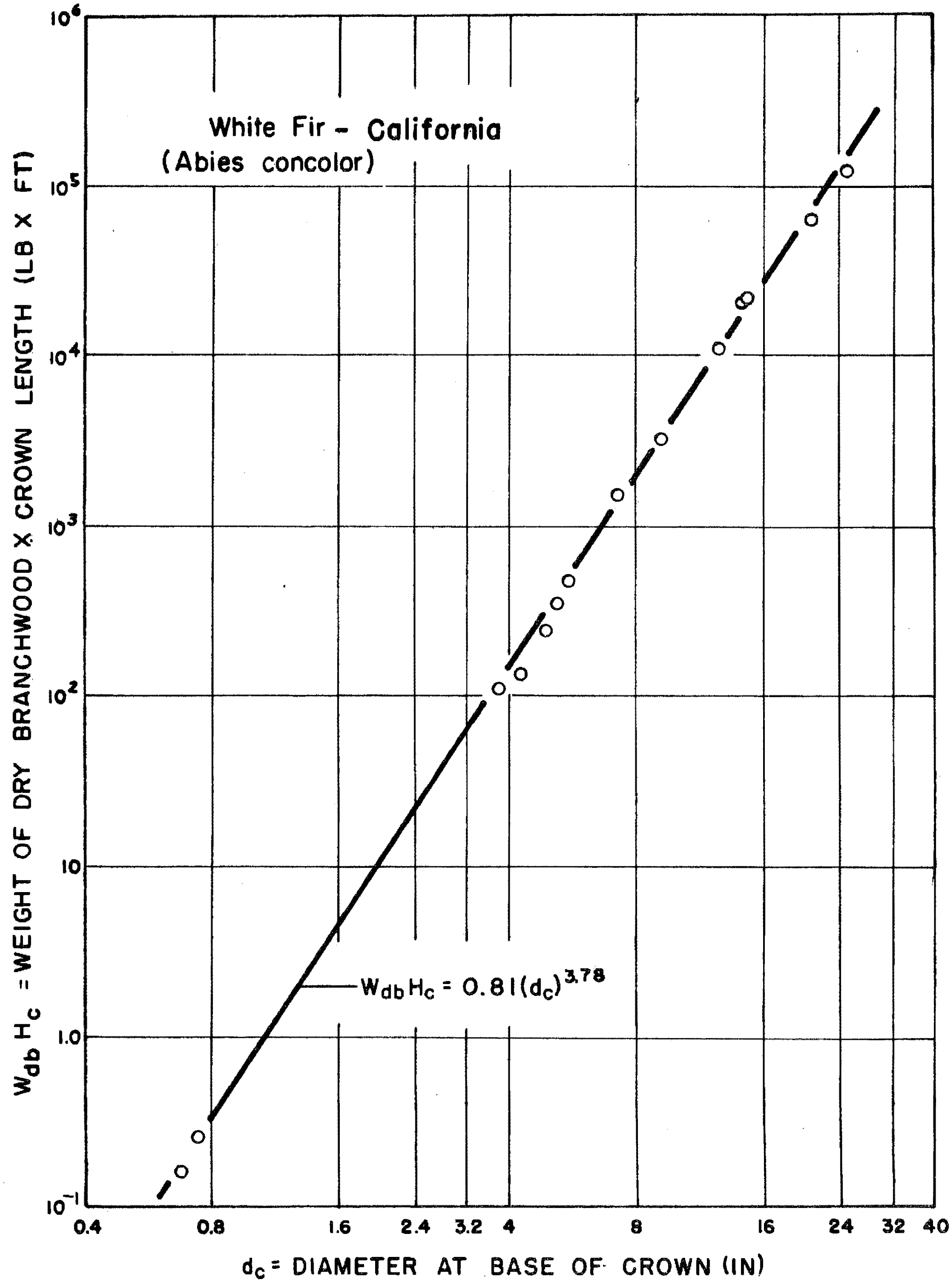

Figure B-22.--Relations between dry branchwood weight, crown length, and base of crown stem diameter inside bark--white fir (California)

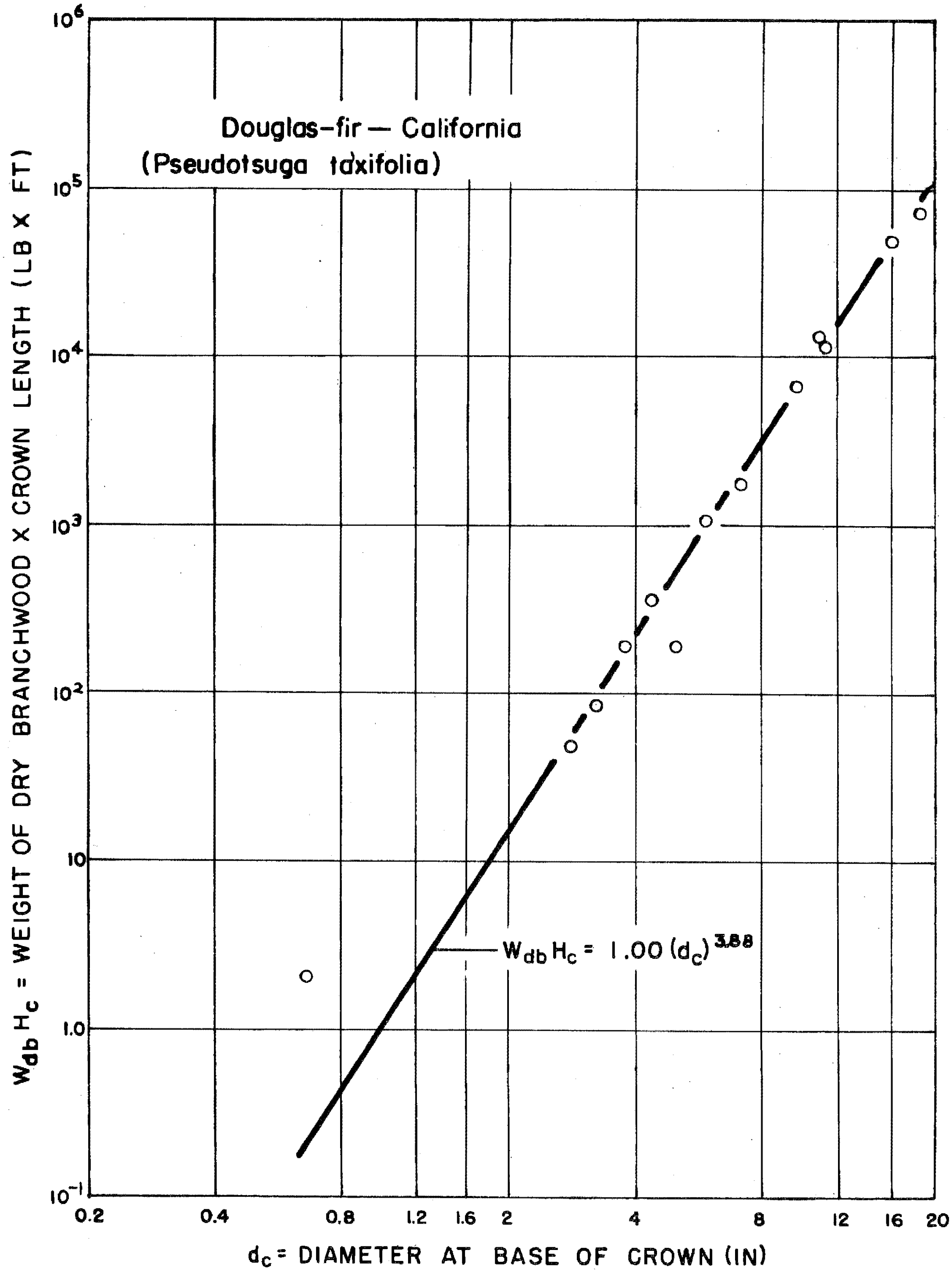

Figure B-23.--Relations between dry branchwood weight, crown length, and base of crown stem diameter inside bark--Douglas-fir (California)

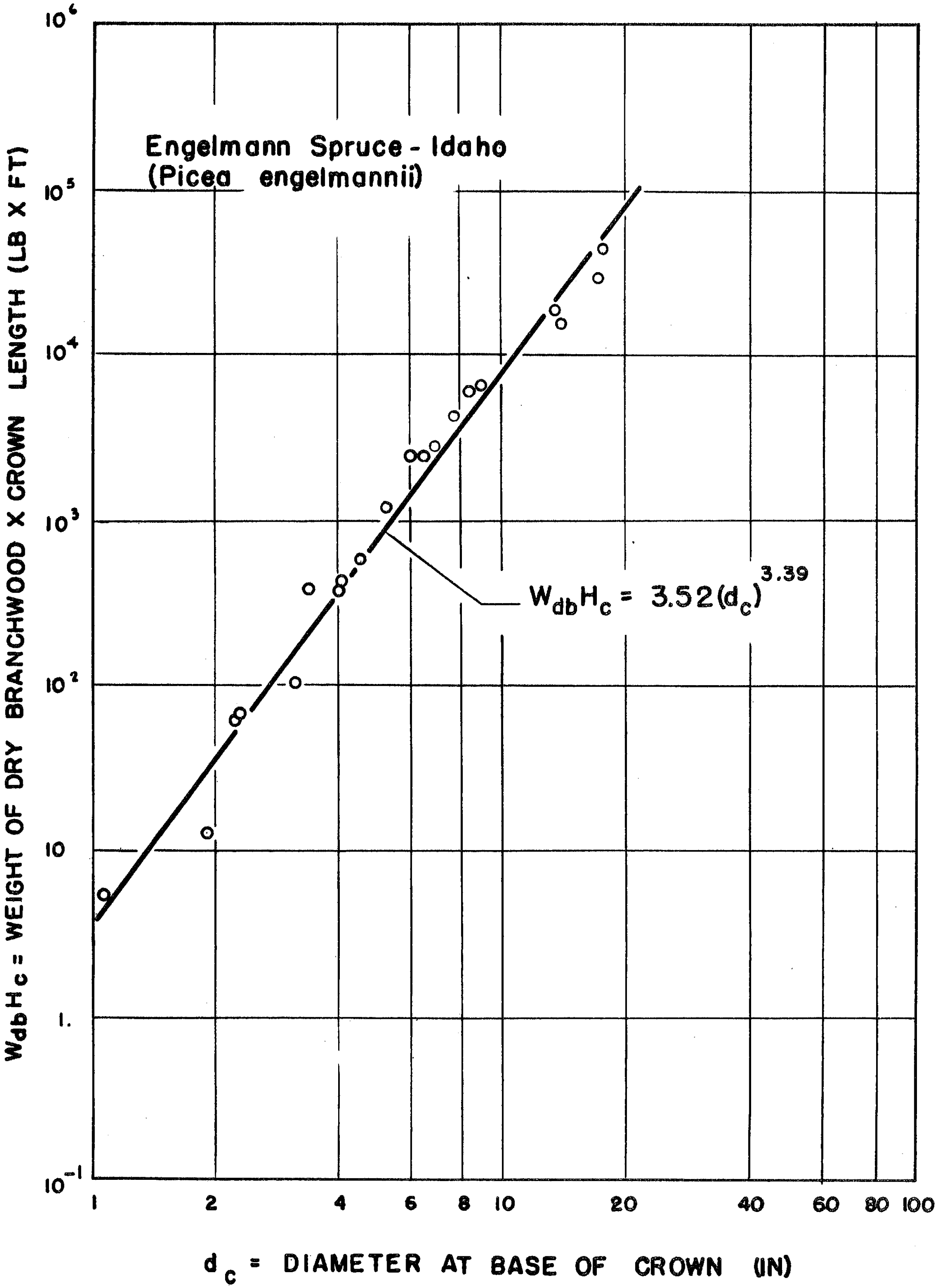

Figure B-24.--Relations between dry branchwood weight, crown length, and base of crown stem diameter inside bark--Engelmann spruce (Idaho)

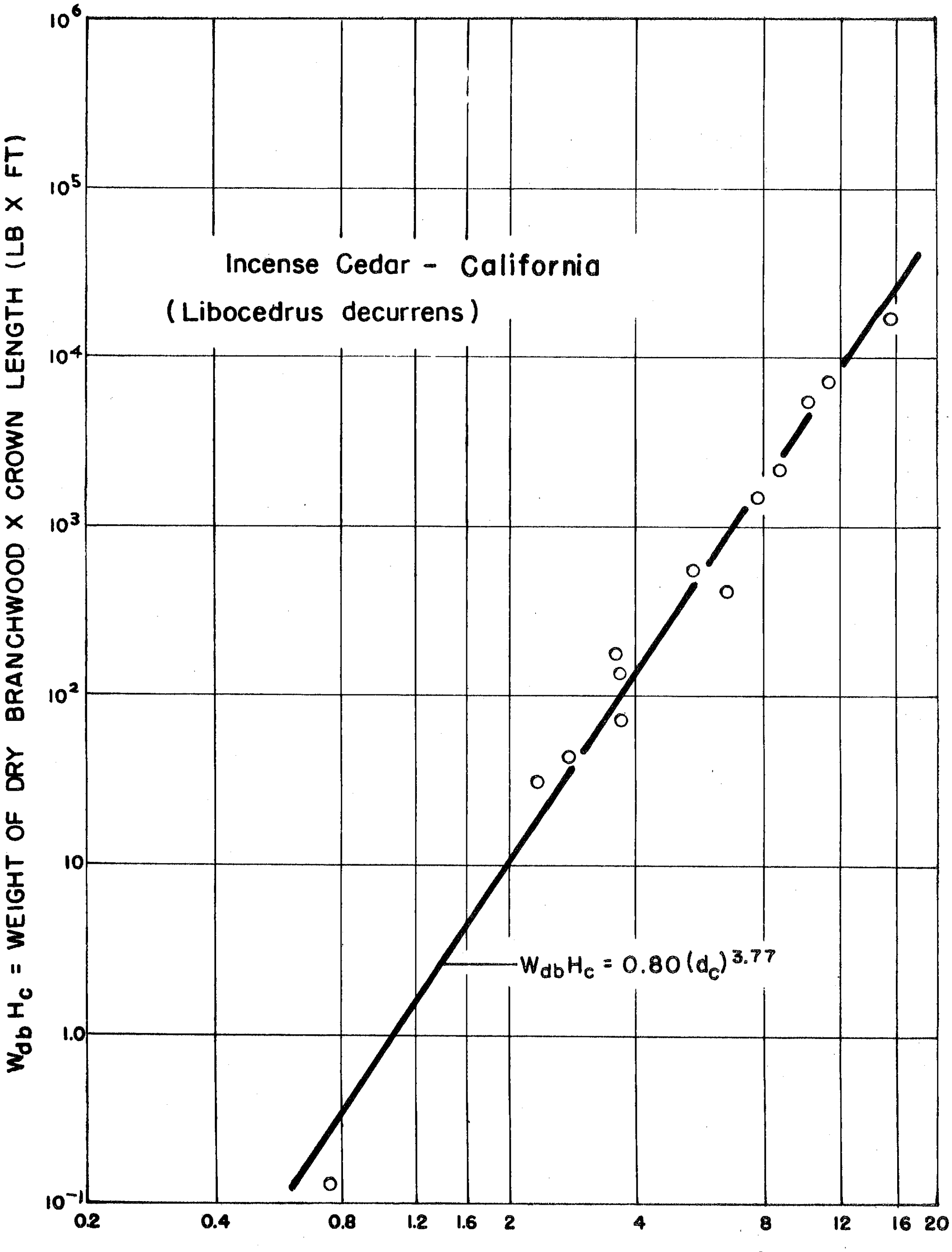

Figure B-25.--Relations between dry branchwood weight, crown length, and base of crown stem diameter inside bark--incense cedar (California)

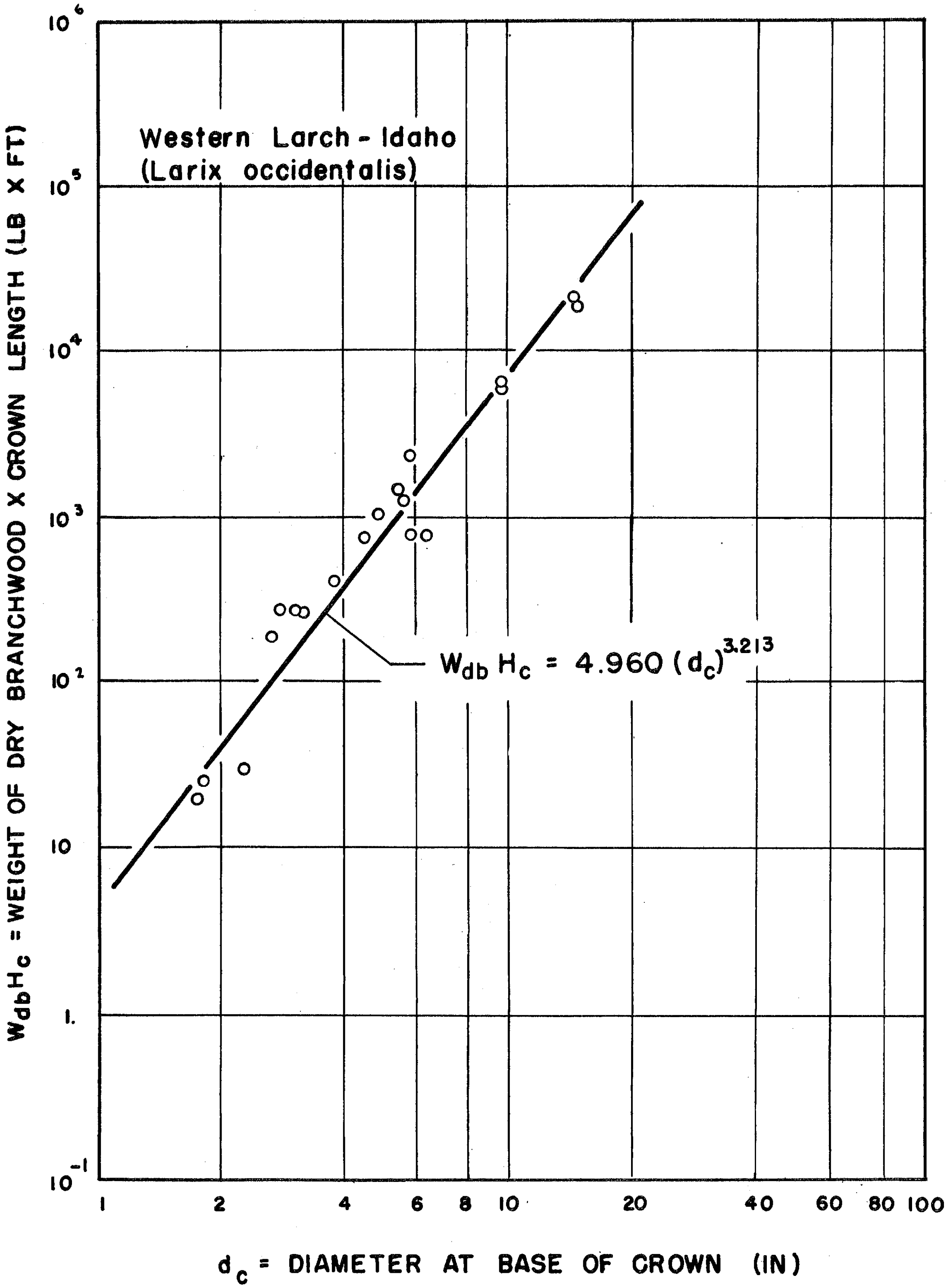

Figure B-26.--Relations between dry branchwood weight, crown length, and base of crown stem diameter inside bark--western larch (Idaho)

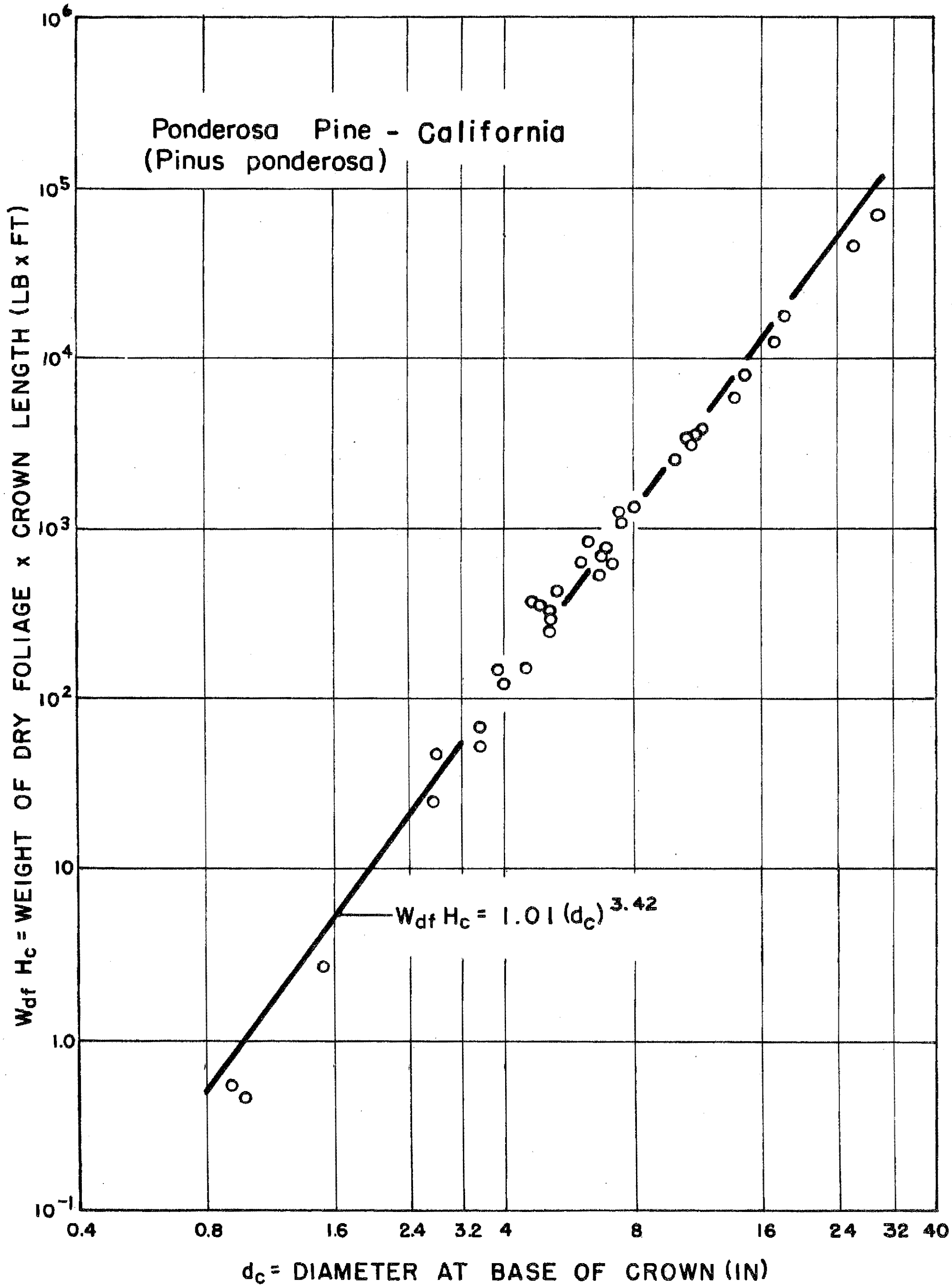

Figure B-27.--Relations between dry foliage weight, crown length, and base of crown stem diameter inside bark--ponderosa pine (California)

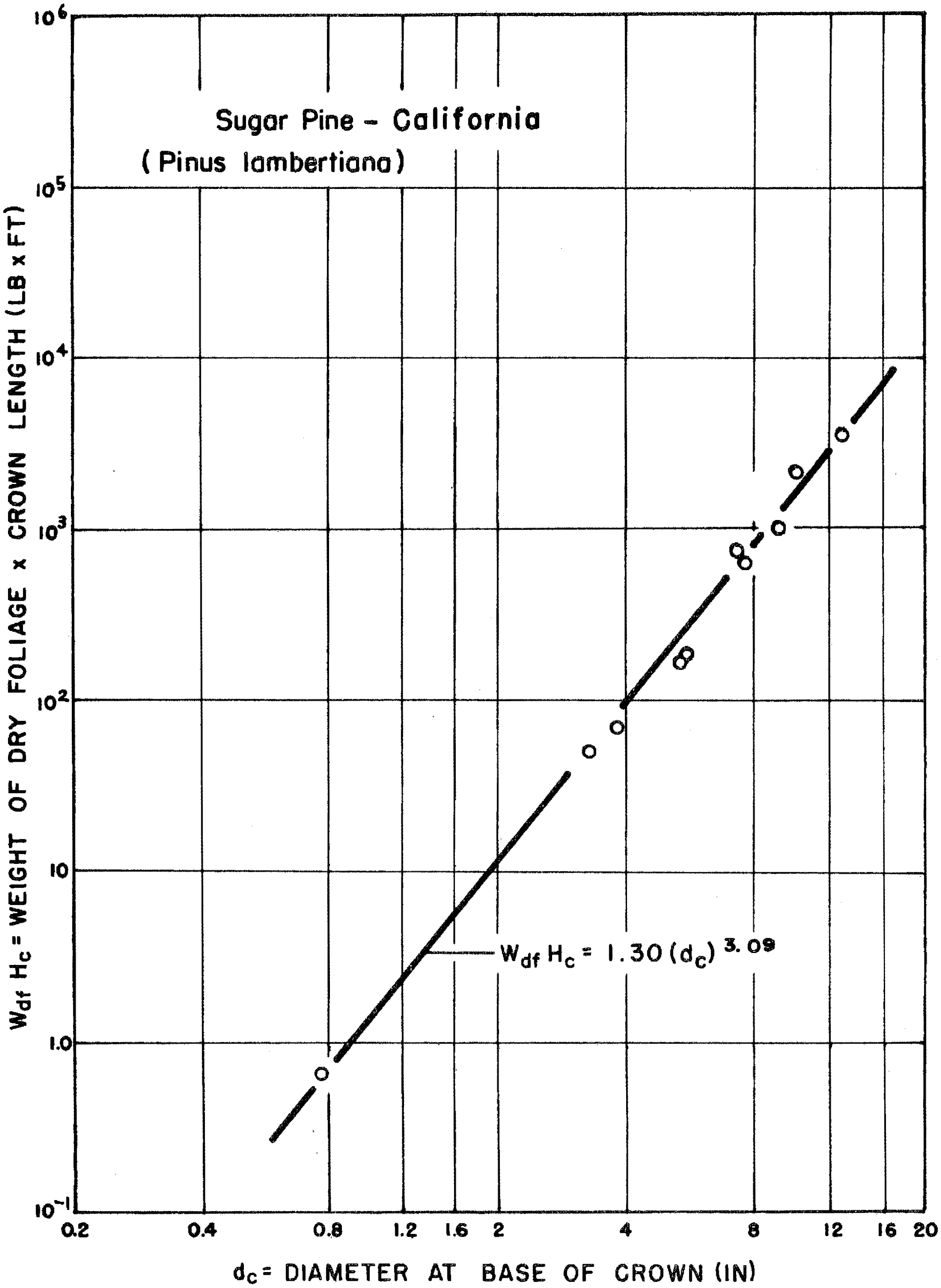

Figure B-28.--Relations between dry foliage weight, crown length, and base of crown stem diameter inside bark--sugar pine (California)

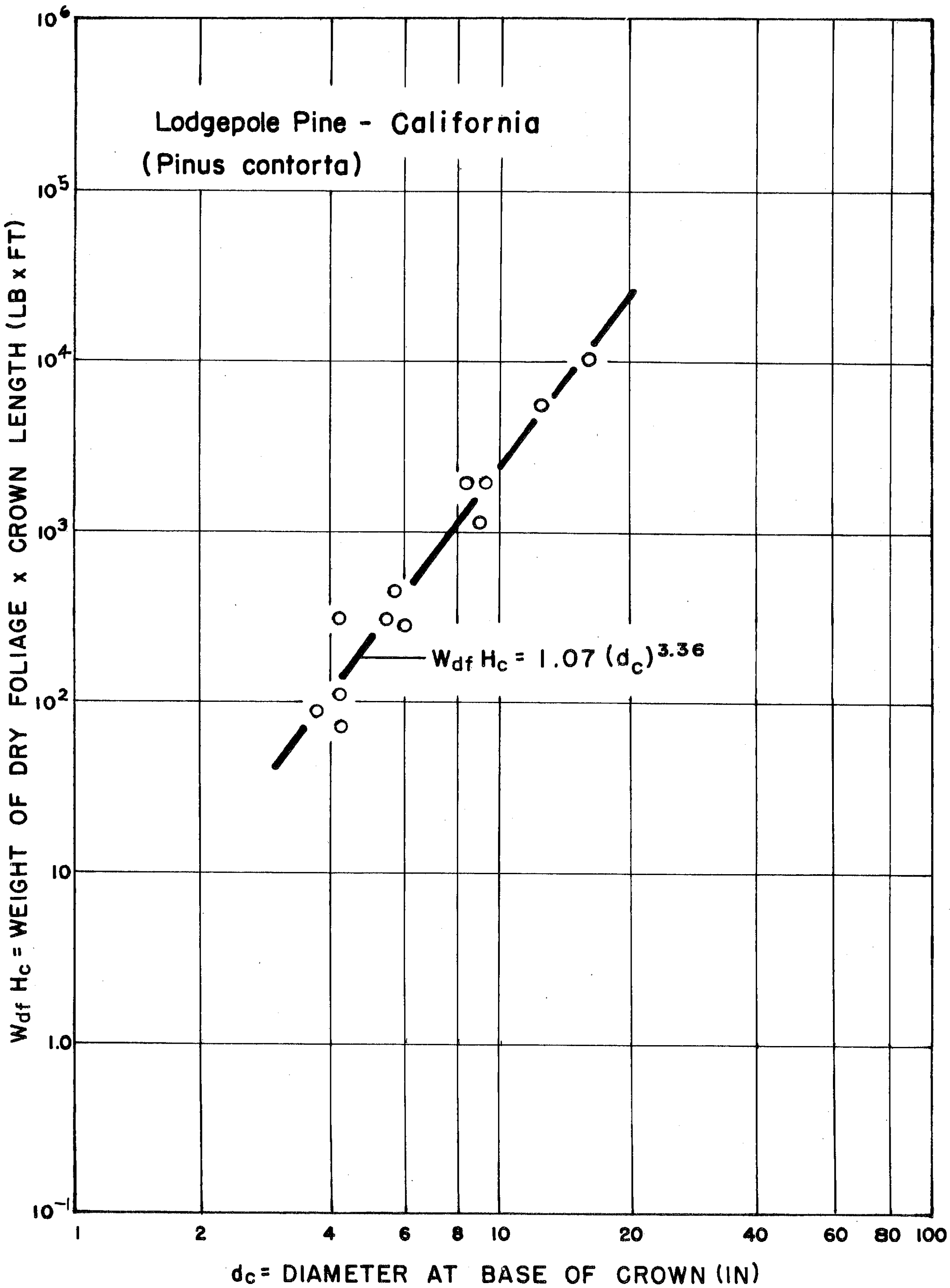

Figure B-29.--Relations between dry foliage weight, crown length, and base of crown stem diameter inside bark--lodgepole pine (California)

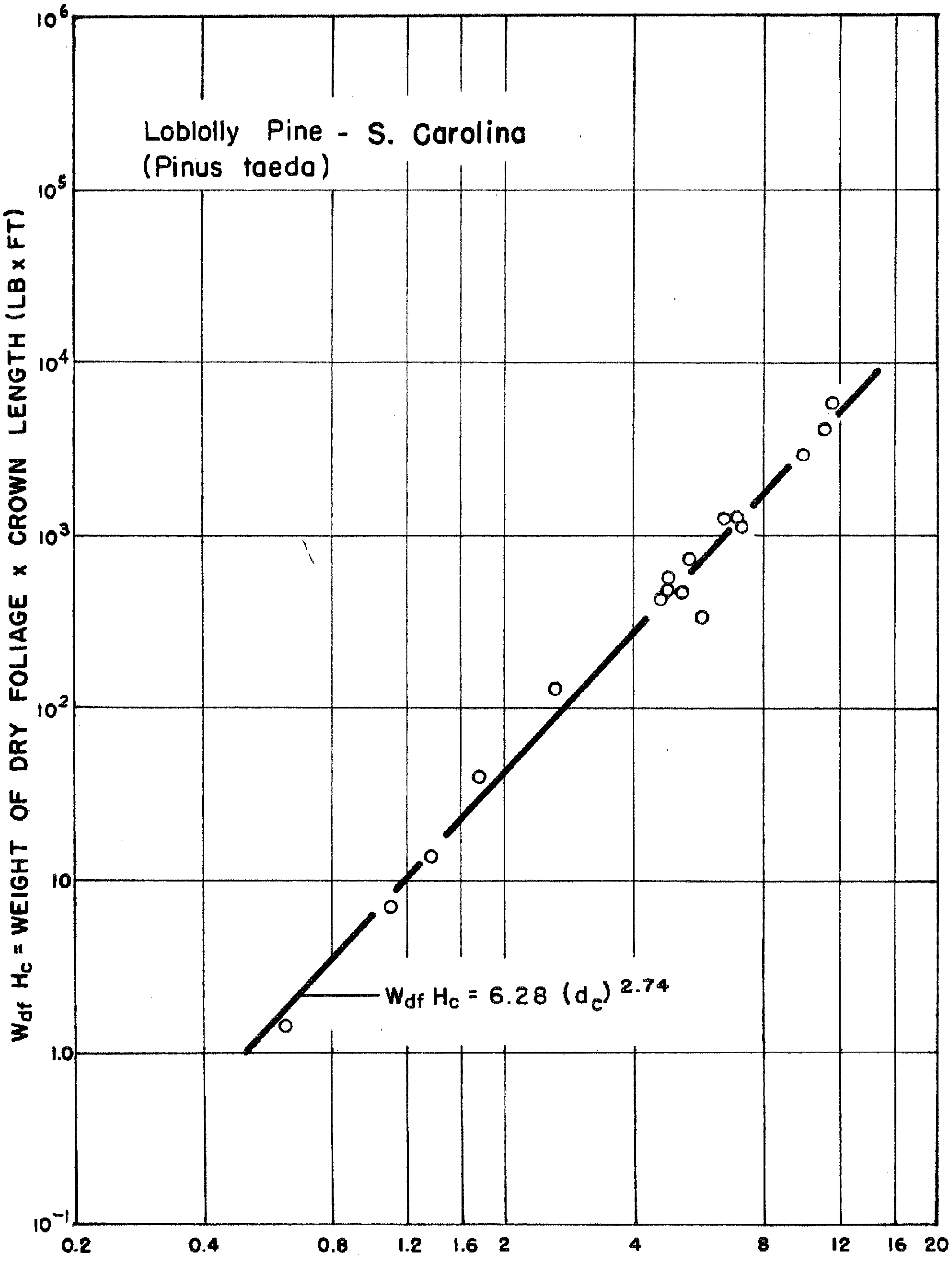

Figure B-30.--Relations between dry foliage weight, crown length, and base of crown stem diameter inside bark--loblolly pine (S. Carolina)

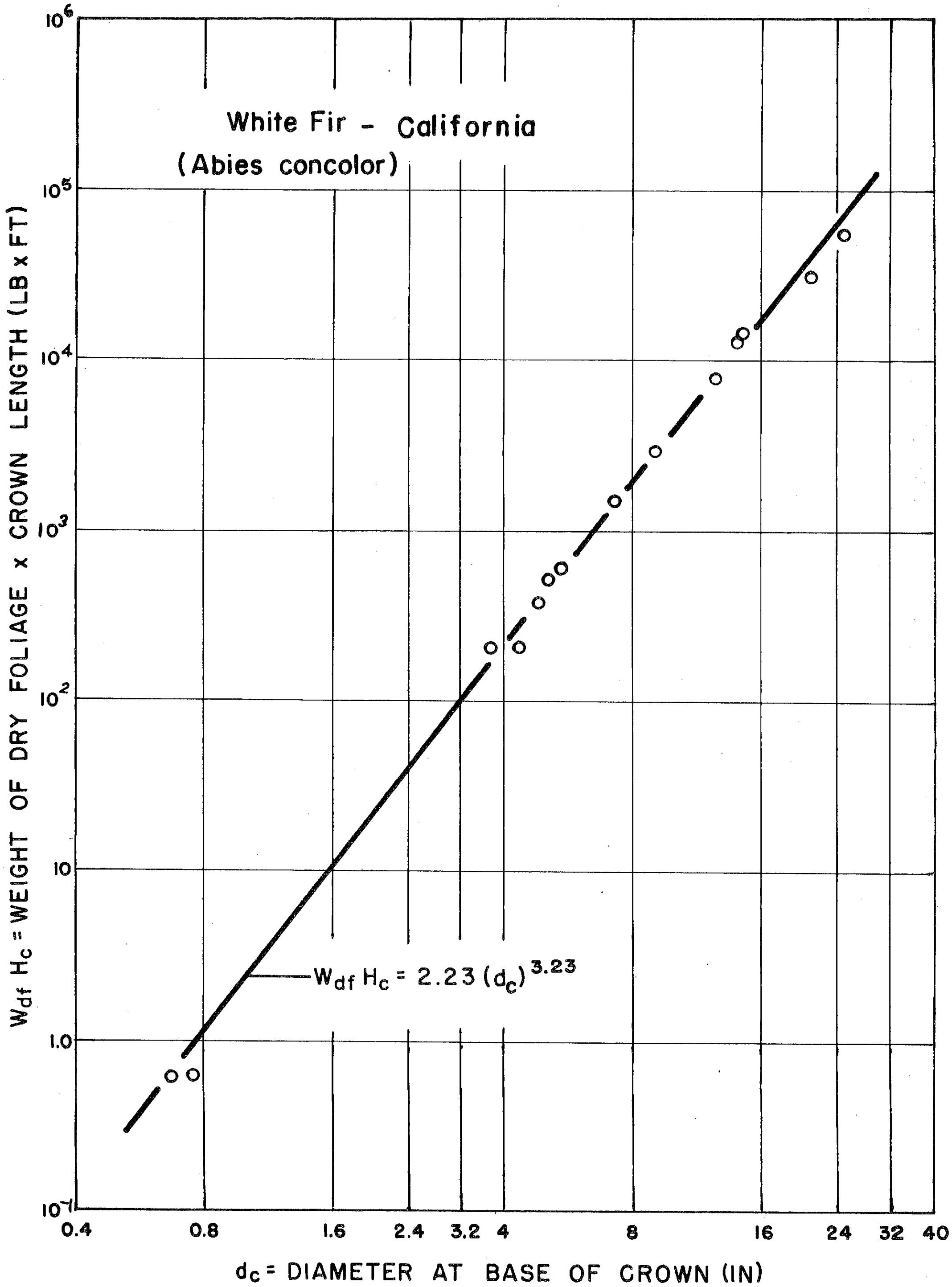

Figure B-31.--Relations between dry foliage weight, crown length, and base of crown stem diameter inside bark--white fir (California)

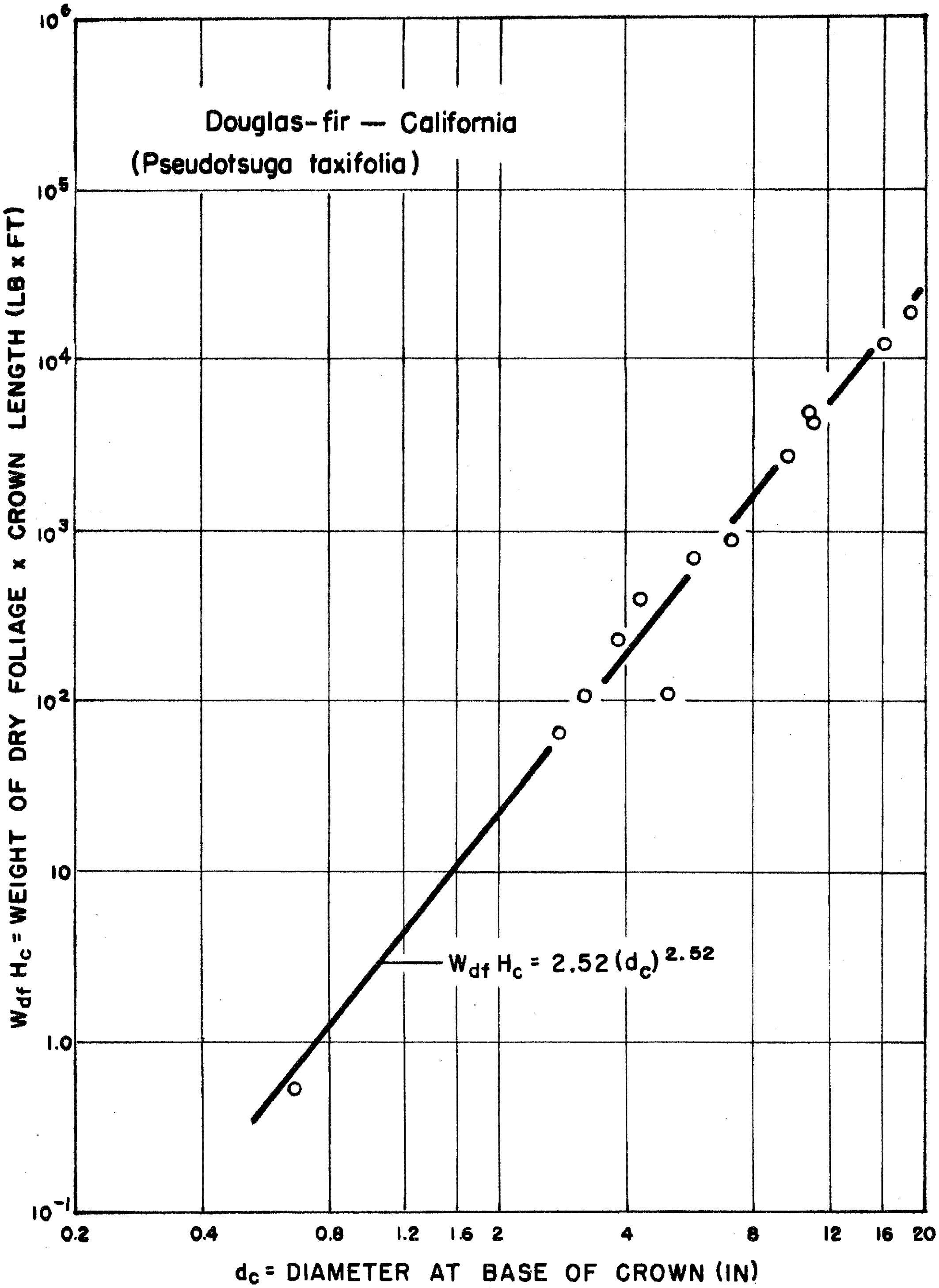

Figure B-32.--Relations between dry foliage weight, crown length, and base of crown stem diameter inside bark--Douglas-fir (California)

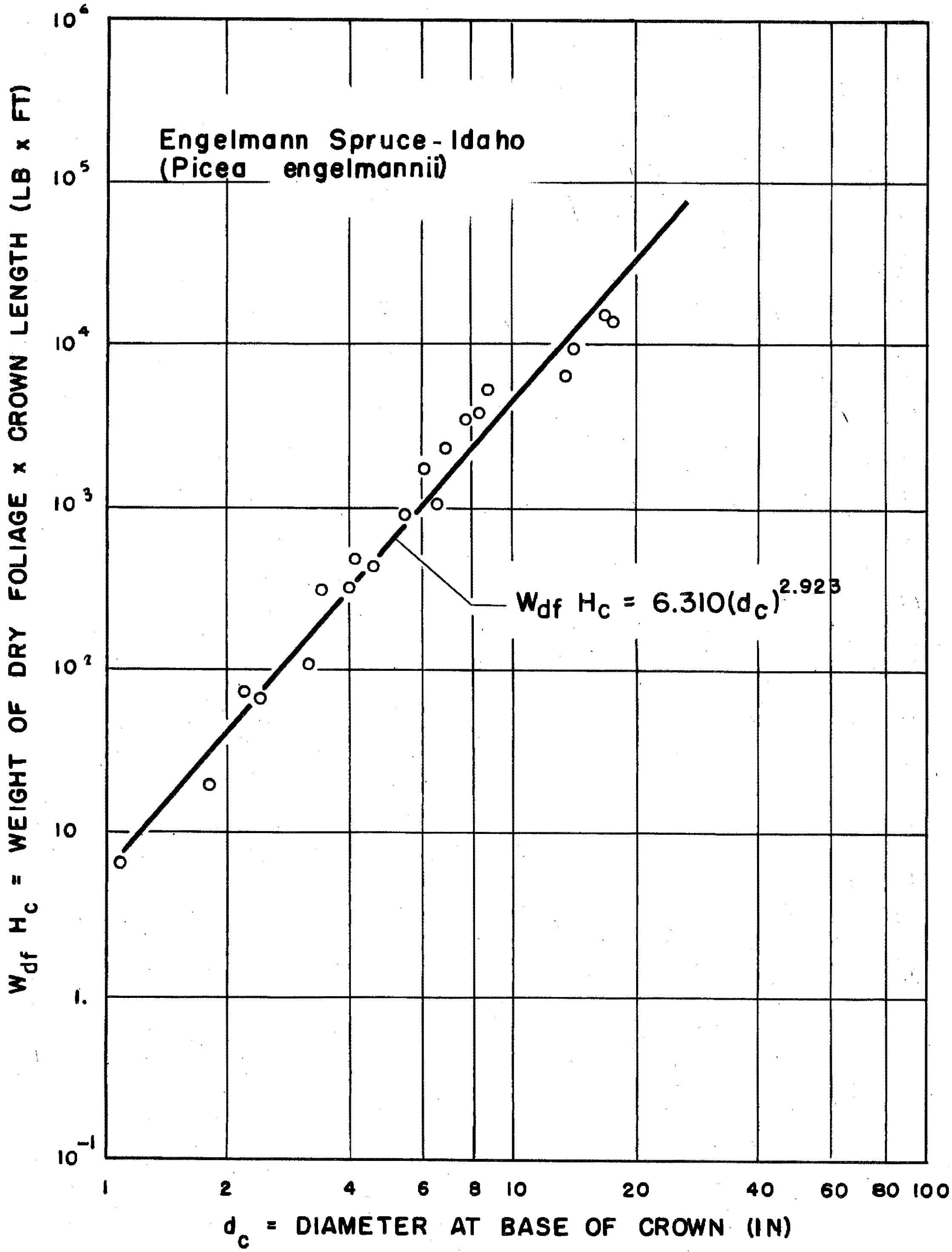

Figure B-33.--Relations between dry foliage weight, crown length, and base of crown stem diameter inside bark--Engelmann spruce (Idaho)

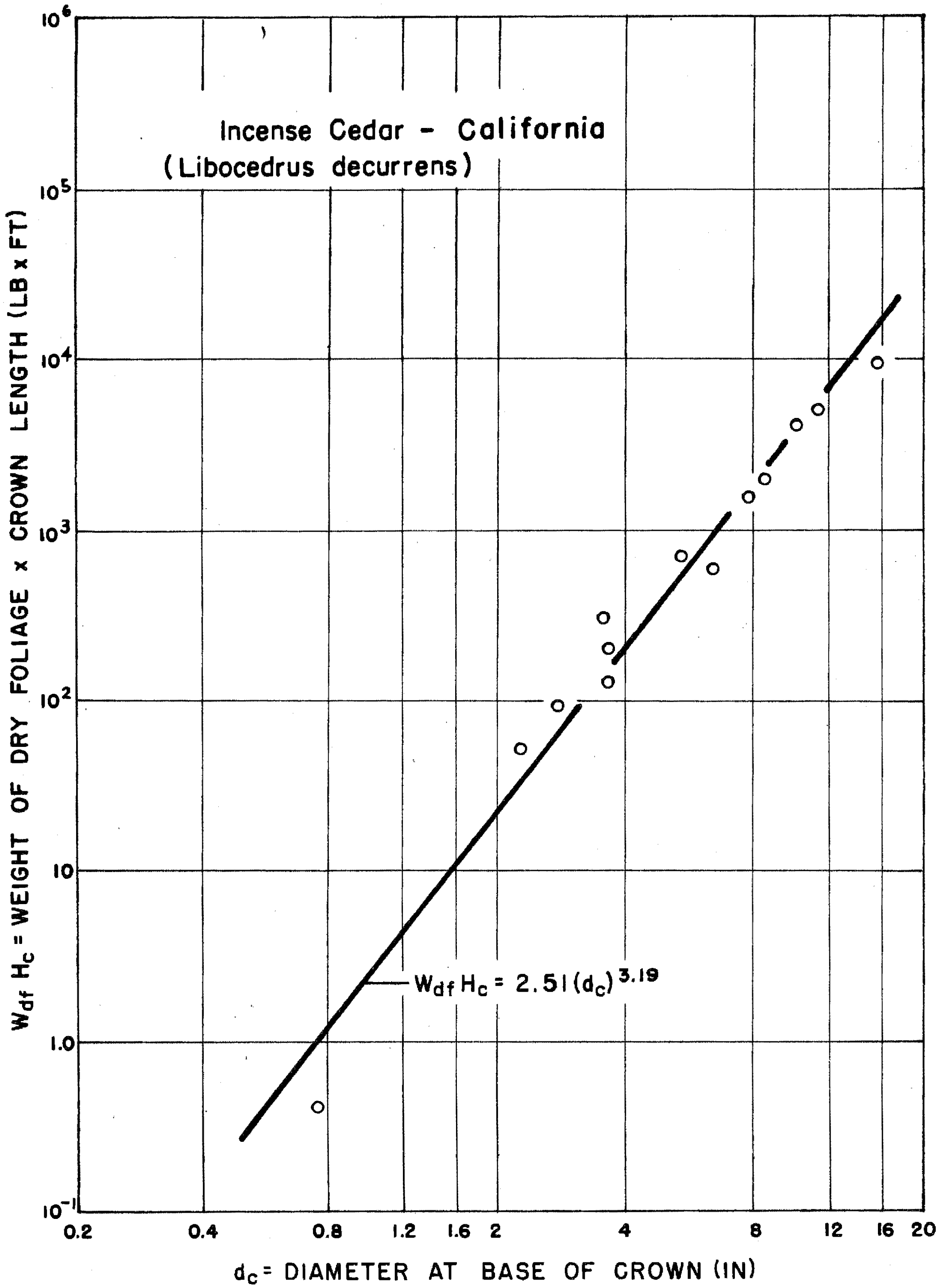

Figure B-34.--Relations between dry foliage weight, crown length, and base of crown stem diameter inside bark--incense cedar (California)

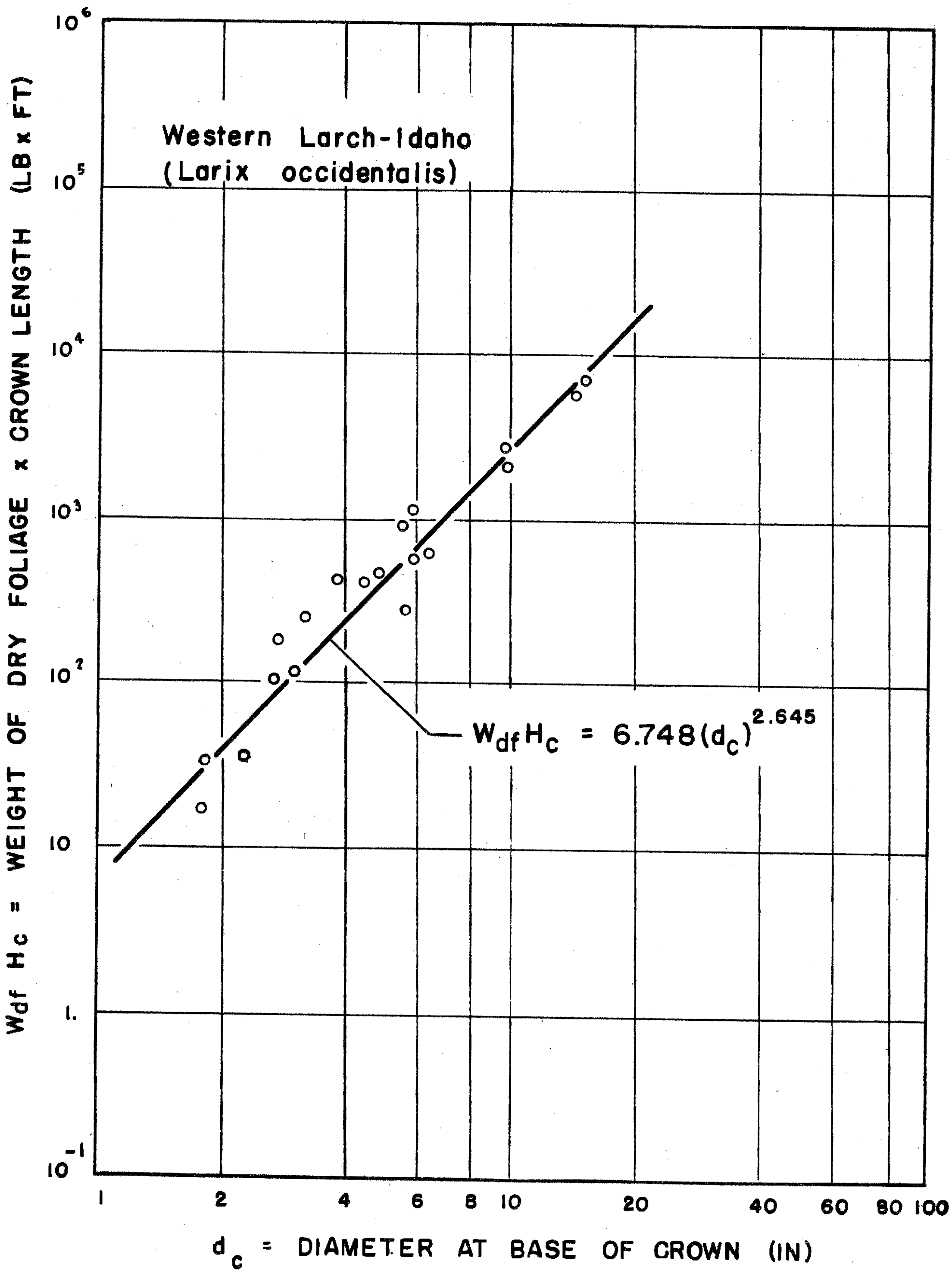

Figure B-35.--Relations between dry foliage weight, crown length, and base of crown stem diameter inside bark--western larch (Idaho)

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NOMENCLATURE

a = Constant in regression equations

b = Regression coefficient in regression equations

bh = Breast height, which is 4.5 feet above ground

Crown = Length of crown over total height of tree, percent

d_b = Stem diameter at 5 feet above ground level, inches

d_c = Stem diameter at base of crown inside bark, inches

d_{bh} = Stem diameter outside bark at breast height, inches

H_{bh} = Height of tree above breast height, feet

H_o = Total height of tree from the beginning of the current year's growth at the tip to 1 foot above ground, feet

H_c = Length of crown from tip of tree to base of crown, feet

W_{dc} = Weight of dry crown, pounds

W_{db} = Weight of dry branchwood, pounds

W_{df} = Weight of dry foliage, pounds